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Juvenile Chinook Migration, Growth and Habitat Use in the Lower Green River, Duwamish River and Nearshore of Elliott Bay, 2001–2003

May 2004

DRAFT

King County

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ACRONYMS

cfs	cubic feet per second
ESA	Endangered Species Act
GIS	Geographic Information System
GPS	Global Positioning System
LWD	large woody debris
MIT	Muckleshoot Indian Tribe
NMFS	National Marine Fisheries Service
OHWM	ordinary high water mark
PIT	Passive Integrated Transponders
RM	river mile
USACE	U.S. Army corps of Engineers
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE

Very little is known about naturally produced juvenile Chinook salmon in the Green/Duwamish River and estuary. While there are several studies (Appendix A**)** regarding Green/Duwamish juvenile Chinook salmon habitat use in the lower reaches of the Green /Duwamish River**,** natural fish could not be distinguished prior to 2000, when marking of almost all hatchery Chinook salmon began on a routine basis. This report, entitled, *Water Resource Inventory Area (WRIA) 9 Juvenile Salmonid Survival Study* (JSSS), presents information collected between 2001 and 2003 regarding natural juvenile Chinook salmon behavior and growth in the lower reaches of the Green River, the Duwamish River, and nearshore of Elliott Bay. These areas are of particular concern due to extensive habitat degradation documented in the *Habitat Limiting Factors and Reconnaissance Assessment Report, Green/Duwamish and Central Puget Sound Watersheds* (Kerwin and Nelson 2000). Less disturbed watersheds have shown that analogous riverine and estuarine habitats provide important rearing habitat for several life history types of juvenile Chinook salmon and other salmonids prior to moving to the open ocean (Reimers 1971; Fresh et al. 1979; Healy 1980 1982; Congleton et al. 1981).

The JSSS was conducted to help elucidate the current status of the Green/Duwamish natural Chinook salmon population, which is influenced by impaired habitat and hatchery supplementation. The information presented in this report will also inform a local salmonid conservation planning effort called the WRIA 9 Habitat Plan. This plan was initiated in response to the 1999 listing of Puget Sound Chinook salmon as threatened under the federal Endangered Species Act of 1973. The Green/Duwamish River fall Chinook salmon stock is one of 21 independent populations in the Puget Sound Evolutionary Significant Unit, which is slated for recovery (PSTRT 2001). The insights provided by the JSSS will support science-based habitat restoration and protection actions leading to the eventual delisting of the species. The JSSS is also intended to create a biological benchmark that can be used to gauge the success of future recovery actions in the watershed.

The JSSS monitored relative abundance, migration behavior, and fish size as primary parameters in assessing the growth and habitat utilization of various index reaches of the Green/Duwamish River by juvenile Chinook salmon and other salmonid species. In 2001, a set of collection sites was established at strategic ecotone locations along the juvenile migration route. Various sampling methods were tested in order to develop the standard sampling protocols used in this study. The study also made use of concurrent data from fish collected and released upstream from the JSSS study area by the Washington Department of Fish and Wildlife (WDFW 2001). WDFW operated a screw trap at river mile (RM) 34.5 and released marked Chinook salmon at the Green River Hatchery located at RM 0.8 on Soos Creek. The above-mentioned study parameters were monitored as fish passed from the mainstem at RM 34.5 and the hatchery into the following five JSSS reaches: the free flowing freshwater river (RM 34.5 to RM 13), the tidally influenced freshwater river (RM 13 to RM 6.5), the Duwamish estuarine transition zone (RM 6.5 to 5.5), the Duwamish River Delta (RM 5.5-0), the and the Elliott Bay nearshore (Figure 1-1). Sampling was conducted in these ecotones in order to gain insight into the habitat types that are currently the most important to juvenile Chinook, and to better understand the behavior of natural and hatchery Chinook salmon in the Green/Duwamish River and estuary.

1.2 OBJECTIVES

The study culminated in 2003 when results from the prior two years of method establishment and initial Chinook salmon size and behavior data collection were used to make more precise estimates of the duration, migration speed, growth rate, and diet of naturally produced juvenile Chinook salmon within each index reach. In addition, the interactions between natural and hatchery Chinook salmon and their respective early life history strategies were investigated in 2003 in mark recapture study. The specific yearly objectives for the JSSS were as follows:

1.2.1 2001

- Establish a suitable monitoring site and method for collecting Chinook salmon juveniles near the downstream end of the free flowing river, a short distance upstream from the tidally influenced Duwamish River, which begins at RM 11.
- Monitor the outmigration timing of Chinook salmon and other salmonids at the RM 13 monitoring site.
- Measure and count all Chinook salmon and other fish collected at the monitoring site to assess relative growth and abundance of the species present at the site throughout the juvenile outmigration period.
- Examine all salmonids for marks and tags to determine the approximate relative abundance and size ranges of natural and hatchery origin Chinook salmon during the outmigration period.
- Compare data collected at the monitoring site with those collected by WDFW staff at the RM 34.5 screw trap and the Green River Hatchery to estimate travel time and growth in the free flowing river study reach.

1.2.2 2002

- Continue to monitor fish at the Lower Green River sampling site at RM 13.0.
- Establish a set of additional sampling sites and develop effective sampling methods in the Duwamish River (RM 11-0).
- Monitor juvenile Chinook salmon in the Green and Duwamish Rivers during the entire outmigration period.
- Estimate the duration of juvenile Chinook salmon residence within the Lower Green River and Duwamish Rivers.
- Measure and count hatchery and natural Chinook salmon to assess growth and relative abundance at the Green and Duwamish monitoring sites.
- Count and measure other species captured to estimate their relative abundance.
- Examine all salmonids for marks and tags to compare the relative growth and abundance of natural and hatchery origin Chinook salmon during the juvenile outmigration period.
- Develop methods to monitor the migration and growth of individual juvenile Chinook salmon using passive integrated transponder (PIT) and acoustical tags.

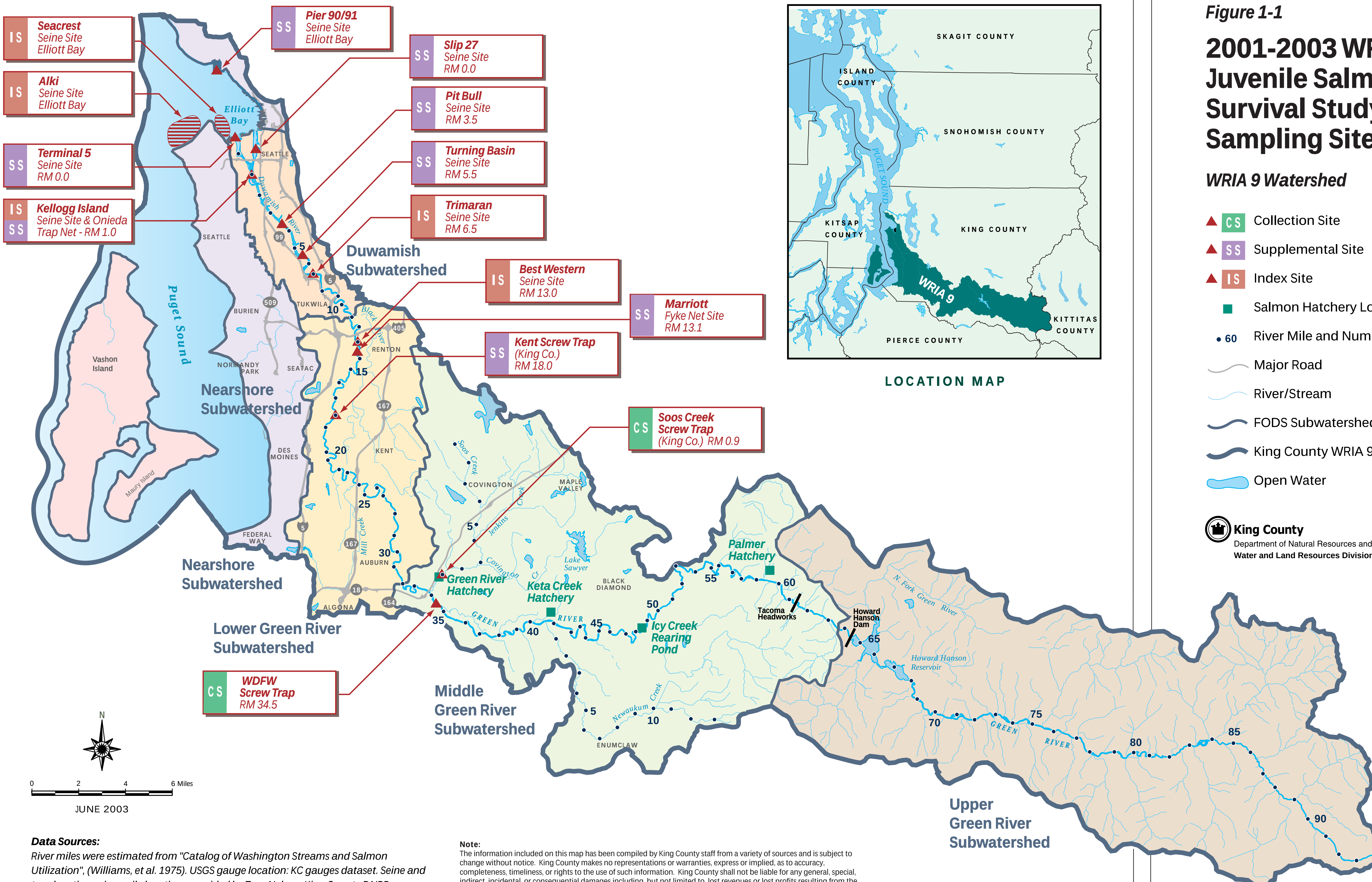

Figure 1-1

2001-2003 WRIA 9 Juvenile Salmonid Survival Study (JSSS) Sampling Sites

WRIA 9 Watershed

- CS Collection Site
- SS Supplemental Site
- IS Index Site
- Salmon Hatchery Location
- • 60 River Mile and Number
- Major Road
- River/Stream
- FODS Subwatershed Boundary
- King County WRIA 9 Boundary
- Open Water

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Data Sources:
River miles were estimated from "Catalog of Washington Streams and Salmon Utilization", (Williams, et al. 1975). USGS gauge location: KC gauges dataset. Seine and trap locations: river mile locations provided by Tom Nelson, King County DNRP. Hatchery locations: data compiled by the StreamNet project with data provided by Washington Dept. of Fish & Wildlife. Streams, lakes, roads: KC wtrcrs, wtrbdy, kcsn. datasets.

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1.2.3 2003

- Estimate the relative abundance, size and temporal patterns of natural and hatchery Chinook salmon and other salmonids in the study reaches by seining with a standard method at five index sampling sites: Best Western (RM 13), Trimaran (RM 6.5), Kellogg Island (RM 0), and two Elliot Bay nearshore sites (Seacrest and Alki).
- Estimate fry migration speed through and the duration of use of the four study reaches by marking discrete groups of naturally produced juvenile Chinook salmon near RM 34.5, and recapturing them within each of the reaches using multiple sampling methods.
- Estimate and compare relative body sizes and diets of naturally produced and hatchery Chinook salmon to investigate potential intra-specific competition and density-dependent growth effects.
- Examine the potential effects of river flow, temperature, and salinity on juvenile Chinook salmon growth and migration behavior, and the potential relationships between these parameters and fish abundance and size during the study period.
- Collect Chinook salmon otoliths and scales in order to examine life history strategies and to support the future investigation of the relationship between life history strategies and survival to adult spawning.

1.2.4 Watershed Habitat History

Prior to Euro-American settlement, which began approximately 150 years ago, the Duwamish River was the gateway for viable natural runs of Chinook salmon and other salmonids that returned to spawn in the 2,600 square kilometer Green/Duwamish watershed in the spring, summer, and fall. These fish formerly migrated through a watershed that included small streams draining into Lake Washington to the north, and headwaters of the White River, which descended down the slopes of Mount Rainier to the south (Figure 1-2, to be revised in final). The Green River lay between these two subwatersheds, and today, due to a series of rapid-fire projects at the turn of the last century, it is the only remaining watershed in this once extensive system of subwatersheds.

Between 1911 and 1916 approximately two-thirds of the original total area of the Green/Duwamish watershed was lost when the White and Black Rivers were removed from the system. The White River, which former merged with the Green River near RM 29 in present-day Auburn, was diverted into the Puyallup River in 1911 to control flooding. In 1916, the Cedar River, which formerly flowed via the Black River into the Duwamish River, was diverted into Lake Washington and thence into Puget Sound via the Lake Washington Ship Canal, Lake Union, and the Hiram S. Chittenden Locks to enable maritime commerce and navigation in Lake Union and Lake Washington. This left only the Green River connected to the Duwamish, and these two waterbodies are now artificially distinguished in name only at RM 11.0, the confluence of the now remnant Black River. The Green River also underwent a watershed-altering project during this period, when, in 1911, salmonids lost access to the upper half of the Green River watershed due to the construction of the City of Tacoma municipal water supply diversion dam at RM 61.

Since 1916, this altered system has been referred to as the Green/Duwamish River. For watershed characterization and planning purposes, the system has been divided into the following subwatershed reaches (Kerwin and Nelson, 2000) that reflect these historic changes: the Duwamish River (RM 0-11), Lower Green River (RM 11-32), Middle Green River (RM 32-64.5) and Upper Green River (RM 64.5-93+).

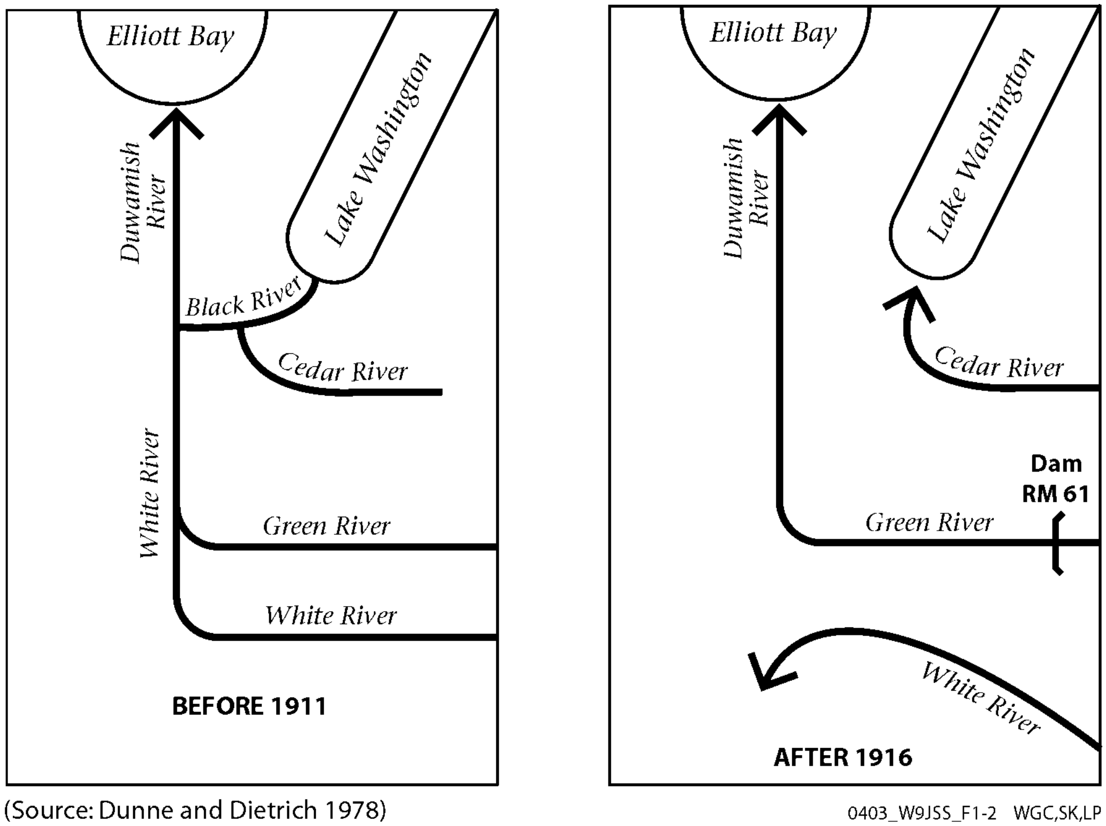

Figure 1-2. Configuration of the Green/Duwamish drainage prior to 1911 and after 1916. (Adapted from Dunne and Dietrich 1978)

These early diversion and projects were the catalyst for land development throughout the Lower Green River watershed. The resulting 70 % reduction in river flows downstream from Auburn also allowed for more efficient filling of the Duwamish mudflats that enabled development of the industrial epicenter of the Pacific Northwest. The diversion of the White River also lowered the elevation of the Lower Green River floodplain (from approximately RM 28 to 11) by seven feet (Dunne and Dietrich 1978), promoting extensive drainage of the Lower Green River valley and more efficient agricultural practices as well as the initiation of small-scale urban development at multiple locations on the valley floor.

Even with the removal of 70 % of the flow from the Duwamish, banks of the Green River still regularly overtopped and threatened developed properties in the lower basin. So in 1962, the U.S. Army Corps of Engineers constructed Howard Hanson Dam 3.5 miles upstream from Tacoma's diversion dam to adjust the flow regime (Figure 1-3) and control flooding in the Lower Green River valley in Auburn, Kent and Tukwila. The added protection from flooding coupled with extensive riverbank armoring allowed greatly intensified urban development and transformation of habitat in the Lower Green River into its current highly simplified and degraded form. At present, the Lower Green River consists of a single thread, extensively armored channel from RM 31 to Elliott Bay. From RM 31 to 25, 82 % of the Green River is flanked by riprap-lined levees and revetments, 95 % of the riverbanks are armored from RM 25 to 11, and 100% of the Duwamish River is armored (Kerwin and Nelson 2000).

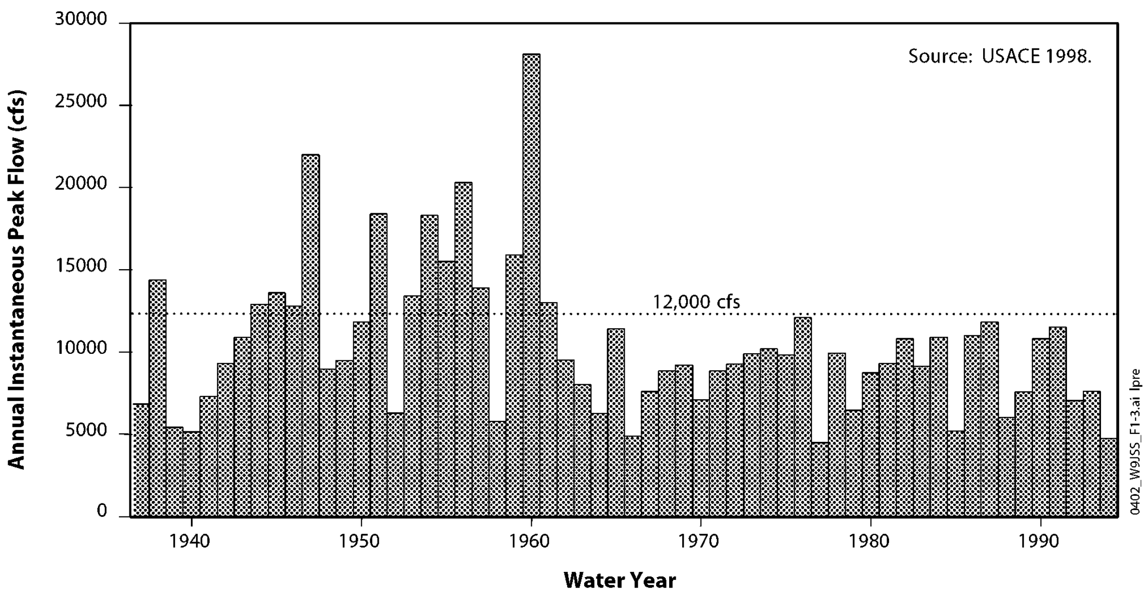

Figure 1-3. Annual instantaneous flows at USGS gauge 12113000, Green River near Auburn, 1937 to 1994. (USACE 1998)

These actions have had devastating impacts on juvenile salmonid rearing habitat throughout this reach, as well as reduced spawning habitat in and upstream from Auburn.

The once extensive freshwater system of channel oxbows, beaver ponds, periodically flooded wetlands, and low gradient streams in the Lower Green River valley has been lost or disconnected from the mainstem. These were the areas where juvenile salmon could avoid the high winter mainstem flows and grow in the quiet, food-rich shallow waters prior to moving into the estuary.

Only 2 % of the original 3.5 km^2 of the historic Duwamish River estuarine mudflats remain today, and the former lower 15 km length of the Duwamish River, which meandered across the valley floor within present-day, Tukwila and Seattle, has been replaced with an 8.5 km long dredged channel (Blomberg et. al. 1988). Freeways, factories, parking lots, wharves, numerous bridges, and an international airport now sprawl where juvenile Chinook salmon formerly acclimatized to salt water, fed, and grew in the productive tide flats prior migrating to nearshore areas. The nearshore areas of Elliott Bay and Puget Sound were densely vegetated with eelgrass and kelp, which sheltered these fish on their journey to the Pacific Ocean.

1.2.5 Study Reach Descriptions

The sampling sites within each study reaches were selected to represent five broad categories of salmonid habitat within the Lower Green River, the Duwamish River and Estuary, and adjacent marine nearshore areas in Elliott Bay. These range from the relatively high velocity, free-flowing, unidirectional flow conditions within the Lower Green River (RM 34.5 - 13); the tidally influenced segment of the Lower Green River and the upper Duwamish River (RM 13 - 7); the freshwater-saltwater transition zone where the riverine, oligohaline character of the river gives way to the euryhaline waters of the estuary proper (RM 6.5 - 5.5); the lowermost portion of the estuary, located within the historic Duwamish tidal delta (now the navigable Duwamish Waterway), which surrounds Harbor Island and flows past mostly industrial lands at the mouth of the river (RM 5.5 - 0); and the nearshore marine habitats along the shorelines of Elliott Bay.

RM 34.5 - 13: Free-flowing Freshwater River:

Instream habitat quality and quantity for juvenile and adult salmonids in this reach of the Lower Green River is significantly altered. Decades of population growth, land use changes and human alterations of the channel and floodplain have greatly simplified the stream habitat in the survey area, including blockage or elimination of many historic off-channel habitats. The channel is confined throughout this reach except for a half-mile stretch of the river just downstream from Auburn Narrows Park (RM 33.5), where the river has created a meander chute cutoff channel. During large floods in 1995 and 1996, overbank flows crossing the narrow neck of meander bend incised a nick point, and head cut the meander cutoff chute through a stand of large 40-year-old cottonwoods. When headcutting broke through at the upstream end it temporarily dislodged additional wood within a historic logjam, which, together with the downed cottonwoods, formed a large matrix of logs in the new location. The older mainstem channel was thereby transformed into a 1.5 RM long side channel which, in addition to providing excellent rearing habitat, also conveys higher flows, i.e., those roughly in excess of 3,000 cfs. Significant deposits of sediments and additional LWD have continued to accrete in both the old mainstem and new avulsion chute channels since the initial channel change. At the same time, the new channel has continued a dynamic evolution including frequent relocations of the main alignment of flow through the complex mosaic of LWD, sediments, and channel forms present at this location. While no systematic investigation of fish abundance has been attempted, even casual observation reveals high densities of juvenile salmonids in this reach as compared to reaches immediately upstream and downstream.

Downstream from there, a nearly continuous system of levees and revetments incrementally constructed over past decades for flood and erosion control purposes prevents channel migration and limits habitat quality and diversity. Habitat types downstream from the logjam are generally homogeneous, and off-channel habitat is limited. Glides are the dominant habitat type, and there are few connections between the main channel and relict off-channel areas of the river (Figure 1-4). While some large pools are present in this reach, the dominant pool-forming factors are manmade structures such as riprap (angular rock used for bank protection) and bridge abutments. Spawning-sized gravel occurs from RM 32.5 to RM 24 (Figure 1-5), and up to one-third of the total Chinookspawning on the mainstem occurs in gravel pockets and bars between RMs 24.0 and 29.0 (Malcom 1999). Sand and silt are the primary substrates in the lower gradient reaches downstream. Connectivity between the riparian zone and instream habitats within this reach is severely impacted by the levees and revetments that line much of the channel, thereby inhibiting the growth of large trees and overhanging vegetation, as well as LWD recruitment. Throughout much of this reach, the adjacent riparian zone is dominated by invasive species (mainly reed canarygrass and Himalayan blackberry) and lacks native vegetation. The presence of invasive vegetation also limits colonization of the riparian corridor by native vegetation, especially tree species that could effectively provide shade, cover, and a future source of LWD. Numerous stormwater and tributary outfalls of varying sizes enter the river along both banks, and many of these structures block fish passage into tributaries and off-channel areas during floods. In several locations, these impacts have been alleviated to some extent by flood control facility repairs that included setting back segments of these facilities landward from the river and revegetating with native riparian plants (Figure 1-6). As the river nears RM 13, the tide begins to take effect and river velocity decreases during low flows and high tides, although the current continues in a downstream direction.

Figure 1-4. Black cottonwood trees and terraced floodplain near Green River RM 27 in the free flowing freshwater river JSSS study reach. Photo from Anchor Environmental 2004.

Figure 1-5. Downstream right bank portion of the large gravel depositional zone at about Green River RM 24 in the free flowing freshwater river JSSS study reach. Photo from Anchor Environmental 2004.

**Figure 1-6. The 212 Street Bridge crossing and river banks at Green River RM 18 in the free flowing freshwater river JSSS study reach.
A King County revetment maintenance project (including LWD placement) occurs along the right bank and is typical of others in the area. Photo from Anchor Environmental 2004.**

**Figure 1-7. Outfall with flapgate in a bank of the Lower Green River.
Photo from Anchor Environmental 2004.**

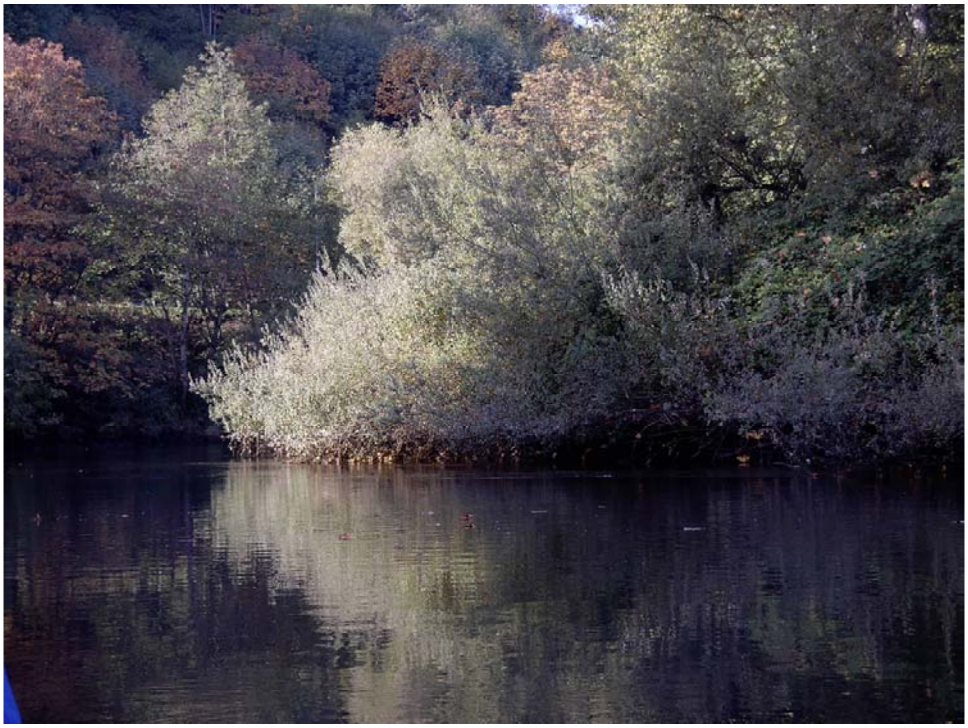

**Figure 1-8. Mature willows on the left bank of the Green River at RM 11.6 in the tidal freshwater river JSSS study reach.
Notice the even high tide mark (lack of vegetation) at the base of the trees.
Photo from Anchor Environmental 2004.**

<u>RM 13 - 7: Tidal Freshwater River:</u>

The structural attributes of habitat found in the upper Duwamish River are similar to those found in urban reaches upstream within the Cities of Auburn, Kent and Tukwila, except that the channel is considerably wider, bank armoring is more pervasive, and flapgates (hinged covers at the pipe outlets that keep mainstem flows from entering during floods) (Figure 1-4) and outfalls are more closely spaced, reflecting the denser urban and industrial land uses that pervade the lands within the historic floodplain on both banks of the river. A recent habitat survey (Anchor Environmental 2004) identified several stands of mature native vegetation–mostly large cottonwoods–and dozens of pieces of large woody debris (LWD), including one key piece of wood in this reach. Although flows within this reach are affected by tidal influence, brackish salinities generally occur in this reach only under low flow conditions in the late summer and early fall, well after the salmonid outmigration season (Figure 1-8). River velocities in this reach are typically slower than in upstream reaches, and the direction of flow reverses on a regular basis during the juvenile salmon migration period during incoming tides. This reach of the river has been affected by extensive filling of historic forested swamps, tidal surge channels, scrub-shrub habitats, and emergent marshes, as well as removal of all but remnant pieces of LWD as well as large volumes of sediment for channel maintenance. As is the case in upstream areas, off-channel habitats, including large marshy areas within the historic Black River corridor, have been almost complete eliminated or cut off from the river by flap-gates.

RM 6.5 - 5.5: Fresh-Saltwater Transition Zone of the Duwamish River:

In this reach the channel is much wider, and shallower, and the water is consistently brackish as the river collides with the marine saltwater wedge. Two large eddies are present, one immediately downstream from a constriction formed by a natural rock weir (a.k.a. West Wind Weir) at RM 6.5, and the other in the Turning Basin at RM 5.5. The shallow, mid-channel depths end at RM 5.5 where regular maintenance dredging occurs. Warner and Fritz (1995) found the highest catches of juvenile Chinook salmon near the upper end of this reach over shallow, gently sloping, intertidal mudflats. This reach also contains intertidal areas composed of sand, gravel and cobble substrates, but these authors found fewer fish there. Compared to the reach downstream and the Elliott Bay shoreline, this reach has the greatest percentage of semi-natural shoreline fringed by intertidal mudflats and a narrow salt marsh fringe. Several small, discontinuous areas of intertidal habitat have also been recreated in this reach, but the extent of remaining intertidal habitat–both natural and restored–is quite small compared to the former aerial extent of these habitats. These projects include efforts to restore intertidal habitat at the mouth of Hamm Creek, which enters the left bank at about RM 5.0, and at the turning basin at RM 5.5. Overhanging structures in this reach are limited to road and rail bridges.

RM 5.5 - 0: Duwamish River Delta:

Before this segment of the Duwamish estuary was industrialized, large volumes of fine sediment deposited on a continual basis in mudflats within a delta that existed with the lower two miles of the Duwamish River. These mudflats were pervaded by a network of shallow, sinuous, ever-shifting distributary channels, fringed by emergent marshes upstream from the delta and along the channel margins. Upstream from this was a large complex of vegetated marshes and mudflats. Almost all of these habitats have been excavated or filled to form Duwamish Waterway, Harbor and Kellogg Islands, and industrial lands along the margins of the historic delta. Kellogg Island, which lies within a meander along the left bank from RM 1.2 to 1.5, is composed of fill and dredge spoils, but is bordered by two shallow remnant channels and is densely vegetated by riparian vegetation, including some mature trees. Bank armoring of the remaining shoreline areas has reduced intertidal habitat to discontinuous narrow fringe areas that are exposed during low tide. In addition, docks, piers, and buildings overhang a total of 2.3 linear miles of both banks of the channel, blocking ambient light and thereby precluding the growth of marsh vegetation, and altering flow dynamics. Upstream from this reach, the only overhanging structures are bridges. During large storm events, suspended sediments from upstream sources now discharge through this almost fjord-like, artificially deepened channel in a turbid plume into Elliott Bay. The Waterway is also regularly dredged for navigation, causing the tide to migrate further upstream than it did prior to conversion of the delta into a maritime industrial area. Weitkamp (In: Seattle's Aquatic Environments: Duwamish Estuary, date?) has speculated that the point of greatest aggregation for saltwater acclimation for Chinook salmon has moved upstream from its former location within the historic Duwamish River Delta (Seattle 2001).

Elliott Bay Marine Nearshore:

As is the case with other Puget Sound river mouths located in urban areas, the Elliott Bay Nearshore has been extensively modified by high-intensity industrial and urban development. In addition to the Port of Seattle's shipping terminal facilities located along the right bank along E. Marginal Way and Alaska Way, on Harbor Island, and along the adjacent left bank in West Seattle, the Seattle central waterfront is flanked by a concrete and timber seawall overhung by large commercial docks, piers and commercial buildings. North of this is the less developed but still highly modified shoreline of Myrtle Edwards Park and Pier 90/91 Park, virtually all of which is armored with riprap. Riparian vegetation is almost non-existent along approximately 10 linear miles of shoreline in this reach, except for sparse ornamental trees and occasional patches of weeds along the riprapped banks. Former gently sloping upper beach areas have been buried by riprap, and riprap that has fallen down the oversteepened slopes into the water now litters the remnant intertidal and subtidal habitats along the shoreline, altering wave interactions and natural sediment movement. In spite of these impacts, kelp beds are present along much of the Myrtle Edwards Park shoreline, in subtidal areas off Piers 90 and 90 and Elliott Bay Marina on the north side of Elliott Bay, and near Alki Point, the outermost extension of the West Seattle shoreline. In fact, the total

**Figure 1-9. High tide on the Duwamish River at RM 6.0 in the fresh-salt water transition zone JSSS study reach.
Photo from Anchor Environmental 2004.**

aerial extent of kelp beds may have increased since the early years of the past century due to colonization on riprap from failed jetties and bulkheads. The role of kelp beds in supporting juveniles of various salmon species is not well documented, but may provide refuge from waves, currents, and perhaps predators. The Seacrest Sampling site is in a small gravelly beach in Seacrest Park northeast of the Port of Seattle's Pier D in West Seattle. From the promontories of Duwamish Head to Alki Point at the north and west ends, respectively, of West Seattle, is a continuous sand and gravel beach within Alki Beach Park. Landward of this is a concrete promenade and a major arterial road flanked by high density commercial and residential land uses. The salinity regime of these areas approximates that of the adjacent waters of Puget Sound, except during large storms when salinities may decrease due to large influxes of fresh water from the river. During these storm events, the turbidity plume and possibly salmon circulate in an easterly direction towards downtown Seattle while nearshore waters to the west (Alki and Seacrest) remain clear.

1.2.6 Current Salmonid Resource

In spite of these habitat impacts, the Green/Duwamish River currently supports all species of anadromous salmonids native to the Pacific Northwest. The migration timing of the most consistently abundant

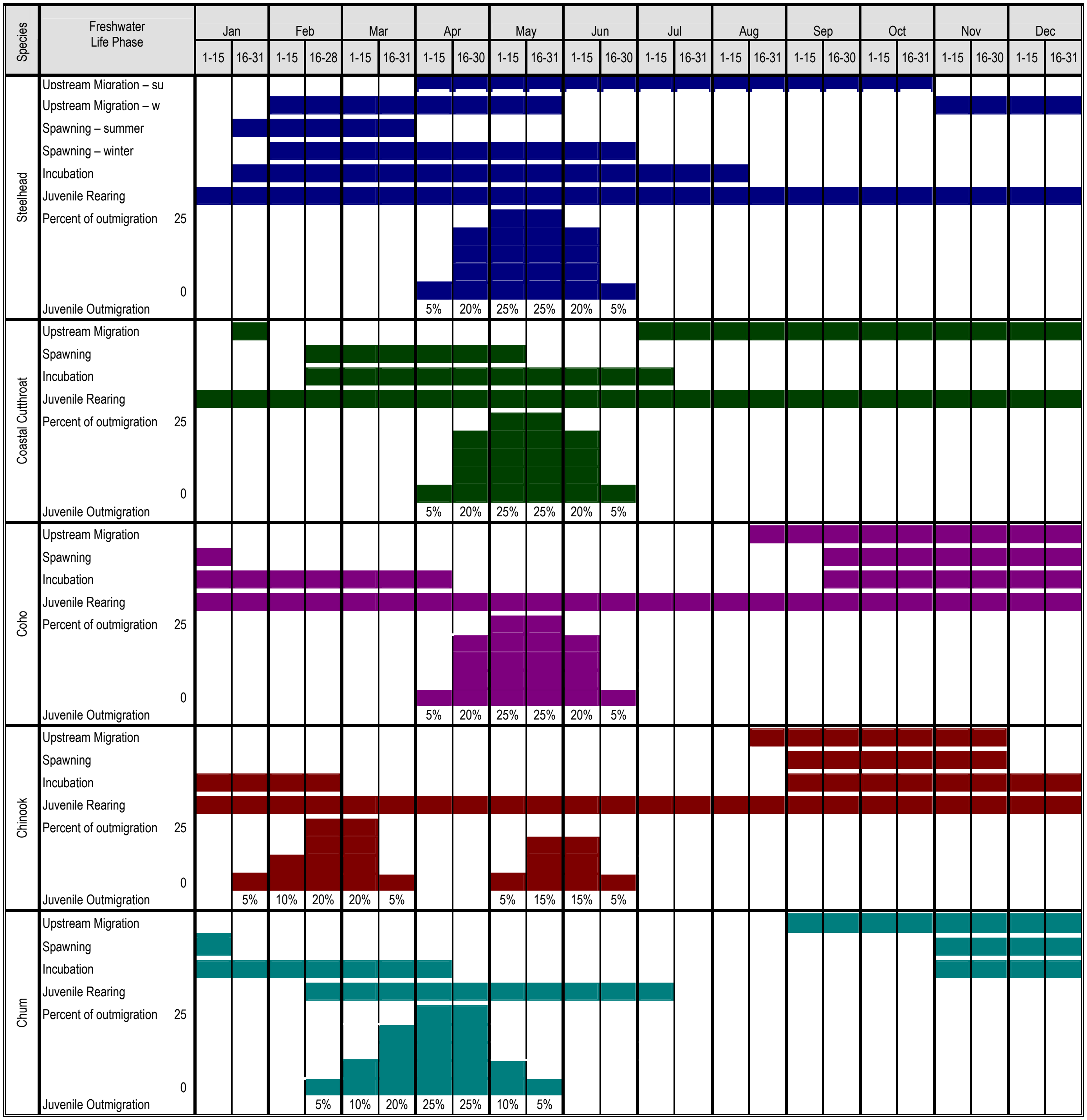

Figure 1-10. Generalized timing of five species of salmonids that use the Green/Duwamish River from Jeanes and Hilgert 2001.
The Chinook juvenile outmigration portion of this figure has been adjusted significantly from the source document to reflect observations from the 2001–2003 JSSS.

species, Chinook, coho, chum, and steelhead, and cutthroat, is shown in Figure 1-10, although sockeye salmon, pink salmon, and bull trout as well as the non-native Atlantic salmon are also found in the river (Kerwin and Nelson 2000).

The Green/Duwamish River Chinook salmon have not shown the same decline in the number of adults returning to spawn in the river as other Puget Sound Chinook salmon stocks. A robust natural spawning run (fish that spawn in the river regardless of hatchery or natural origin) has persisted in the Green/Duwamish basin, and it consistently exceeds the escapement goal of 5,750 Chinook salmon (Figure 1-11) set by WDFW in the 1970s (Kerwin and Nelson 2000). It is currently estimated that a large proportion, ranging from 25 to 83 % and averaging 56 %, of the natural escapement is composed of hatchery reared Chinook salmon that spawn in the river (Kerwin and Nelson 2000). These estimates have been difficult to verify since only a small percentage of hatchery Chinook salmon were marked prior to 2000.

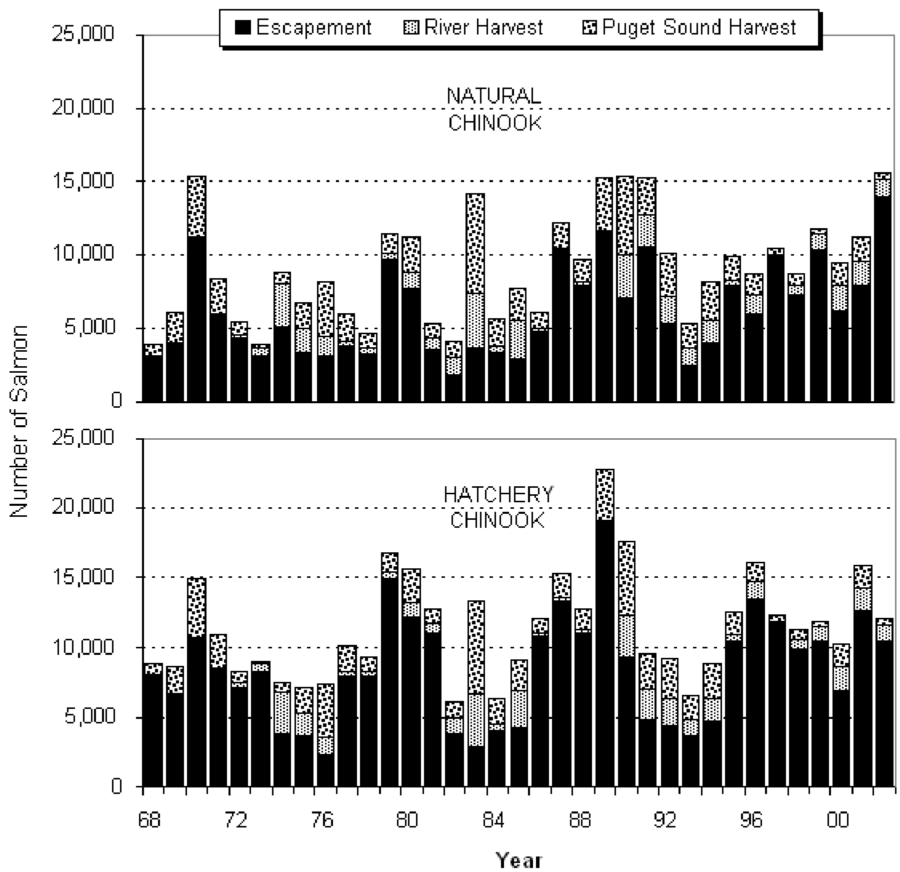

Figure 1-11. Estimates of spawning escapement and harvest (commercial and Indian) of natural (upper graph) and hatchery Chinook salmon (lower graph) returning to the Green River, 1968-2002.
Natural spawning escapement is defined as any adult spawning in the river, regardless of origin (hatchery or natural).

This longstanding inability to adequately differentiate between natural and hatchery produced Chinook salmon has also hindered the assessment of juvenile habitat utilization, migration behavior, growth, and survival. Most previous juvenile Chinook salmon studies (Appendix A) were carried out downstream from the Chinook salmon producing Soos Creek, Keta Creek, and Icy Creek hatchery sites. These pre-2000 studies could not differentiate natural and hatchery fish following the annual release of three to five million hatchery Chinook. In 2000, mass marking by adipose fin clipping of hatchery Chinook salmon occurred for the first time, initiating a new era for juvenile salmonid research in the watershed.

Also in 2000, for the first time a screw trap was operated by WDFW staff at RM 34.5 to estimate natural salmon production. This trap study documented a bimodal outmigration of natural subyearling Chinook, which has been confirmed in the present study. An early migration of small (about 40 mm fork length) fry was observed to peak in early March, followed by a second, smaller peak in late May of larger (about 72 mm) fingerlings (Seiler 2000). This was the first definitive indication of differences in natural fry and fingerling rearing strategies in the Green/Duwamish watershed.

1.2.7 Possible Chinook Salmon Rearing Strategies

It is believed that historically, naturally produced Green River juvenile Chinookexhibited a diversity of rearing strategies prior to entering the Pacific Ocean. The duration and spatial distribution of fish within freshwater, estuarine, and marine habitats distinguish these traits. The use of various habitats provides overall resiliency within the population to survive in the face of interannual changes in environmental conditions. A spatially and temporally distributed population is thus considered a key parameter in determining the viability of Chinook salmon populations (McElhany et al. 2000**).**

Kerwin and Nelson (2000) suggested that there is potential for at least four important juvenile Chinook salmon life history trajectories to exist in the Green/Duwamish River. These potential strategies have been defined by Hayman et al. (1996**)**, based on the timing of entry into the estuary (Figure 1-12).

<u>Emergent Fry</u>

Emergent fry migrate to estuarine rearing habitats immediately after emergence, at an average length of approximately 40 mm. This trajectory is thought to be composed of naturally produced Chinook salmon because hatchery Chinookare released later in the spring at a larger size. Under this trajectory, Chinook salmon have the potential to spend six or seven months in the river and estuary. However, studies conducted prior to 2001 in the Duwamish River found very few fish in this size range in the estuarine portions of the lower river.

<u>Fry/Fingerling</u>

Fry/fingerlings migrate to estuarine and marine nearshore habitats at lengths ranging from 45 to 70 mm. These Chinookare considered to be naturally produced due to the timing of their arrival in the upper Duwamish River in April and early May, prior to hatchery releases. They may occupy the Duwamish River and nearby estuarine shorelines for three to five months before moving offshore.

<u>Fingerlings</u>

The terms fingerling and smolt are sometimes used synonymously by biologists to describe Chinook salmon that are physiologically prepared to encounter estuarine conditions. Fingerlings migrate to estuarine or marine shoreline habitats at lengths that typically equal or exceed 70 mm, and comprise both hatchery and naturally produced chinook. They rear for a relatively prolonged period in freshwater and arrive in the Duwamish River during May and June, spending about two weeks there prior to moving offshore.

Yearlings

Yearlings, also called stream-type fish, migrate to estuarine habitat at one year of age and are thought to move quickly to offshore marine habitats in the Pacific Ocean. Some of these large smolts (140 to 175 mm) appear in the Duwamish River in mid-May and probably consist mostly of hatchery-reared fish (Warner and Fritz 1995). The proportion of naturally produced Chinook yearlings is not known.

The potential life histories listed above are based on information from studies of salmonid utilization of the Middle Green and Duwamish River reaches (see Appendix A) of the Green/Duwamish River. These studies indicate that the lower river and estuary are especially important to juvenile Chinook salmon that comprise the fry/fingerling, fingerling, and possibly other unknown rearing strategies. Understanding the habitat needed to spatially distribute and support a variety of life history types is key to developing watershed recovery efforts in WRIA 9.

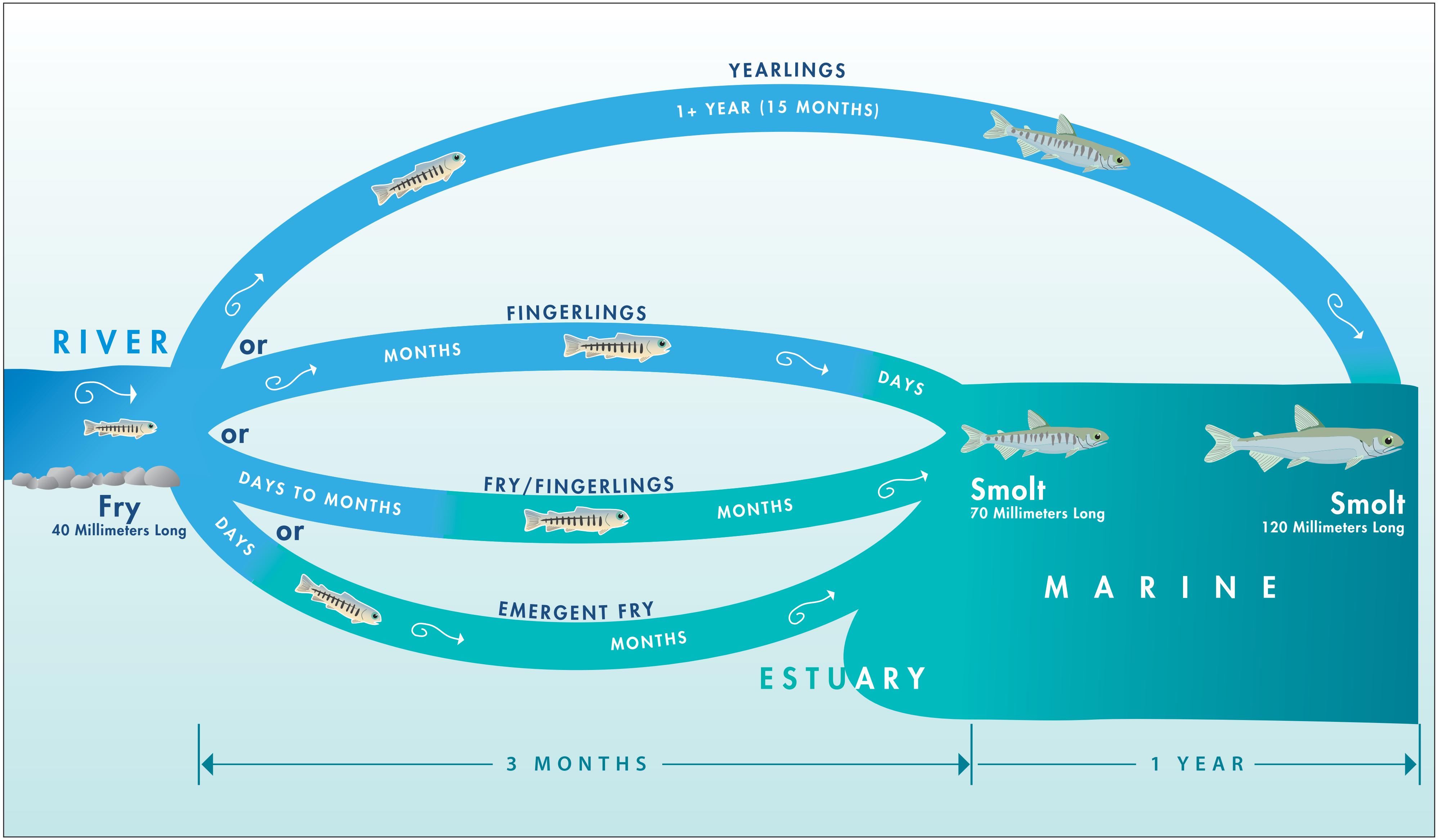

Figure 1-12

Green/Duwamish River Chinook Juvenile Rearing Trajectories

WRIA 9 Juvenile Salmonid Survival Studies 2001

Produced by: King County DNRP GIS & Visual Communications Unit
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Department of
Natural Resources and Parks
Water and Land Resources Division

CHAPTER 2. METHODS

2A. 2003

In 2003, consistent index site seining was combined with a mark and recapture study of naturally produced juvenile Chinook salmon to examine migration and growth through the lower 34.5 miles of the Green/Duwamish River and into Elliott Bay. Sampling of index sites allowed for the comparison of relative abundance, size, and prey consumption of wild and hatchery Chinook salmon collected at five strategically located areas along their migration route. The mark-recapture study monitored in a more precise fashion, the migration of marked groups of Chinook fry. The index and other study sites are presented in Figure 1-1 and Table 2-1. In addition to the information gathered by this study, the WDFW staff provided weekly Chinook salmon catch and length data collected from the RM 34.5 screw trap. These data represented fish that reared in Middle Green River subwatershed (RM 64. 5–32) and were compared with lengths and timing of Chinook salmon as they migrated through the study index sites.

Table 2-1. 2001 to 2003 WRIA 9 Juvenile Salmonid Survival Study sampling site names, locations, and habitat types.

Site Name	Location	RM	N. Latitude	W. Longitude	Habitat
Soos Creek Screw Trap	Soos Creek	0.9	47.18.42	122.09.54	Freshwater Stream
WDFW Screw Trap	Green River	34.5	47.17.36	122.09.54	Freshwater River
Kent Screw Trap	Green River	18	47.24.44	122.15.51	Freshwater River
Marriott	Green River	13.1	47.27.32	122.14.44	Freshwater River, Tide Influenced
Best Western	Green River	13	47.27.36	122.14.52	Freshwater River, Tide Influenced
Codiga Farms	Duwamish River	8.5	47.29.20	122.16.11	Freshwater River, Tide Influenced
Trimaran	Duwamish River	6.5	47.30.13	122.17.46	Estuarine Transition Zone
Turning Basin	Duwamish River	5.5	47.30.43	122.18.08	Estuarine Transition Zone
Pit Bull	Duwamish River	3.5	47.31.54	122.18.08	Estuarine Mudflat
Kellogg Island	Duwamish River	1	47.33.26	122.20.45	Estuarine Mudflat
Slip 27	East Duwamish Waterway	0	47.34.44	122.20.30	Nearshore Marine
Terminal 5	West Duwamish Waterway	0	47.35.04	122.21.40	Nearshore Marine
Pier 90/91	Elliott Bay	Northeast shoreline	47.37.50	122.22.42	Nearshore Marine
Seacrest	Elliott Bay	Southwest shoreline	47.35.16	122.22.39	Nearshore Marine
Alki	Elliott Bay	Southwest shoreline	47.35.11	122.23.58	Nearshore Marine

2A.1 INDEX SITE SEINING

2A.1.1 Sites and Schedule

Index sites were selected strategically to sample fish as they exited the following set of discrete habitat areas as described in the introduction: Best Western (RM 13), Trimaran (RM 6.5), Kellogg Island (RM 1), Seacrest (Elliott Bay) and Alki (Elliott Bay). The index site locations relative to the watershed are shown in Figure 1 and the location attributes are described in Appendix B with latitude and longitude coordinates. A beach seining procedure, using what is referred to in this report as the "river seine" was selected as a standard fish capture method at all index sites. The river seine allowed efficient net deployment during slack tides at estuarine sites and in fast-flowing water at the Best Western site. This method thus allowed for relative comparisons to be drawn of various study parameters at multiple sites throughout the period of juvenile salmonid migration. Index sites were initially sampled on January 24 and sampling continued once per week until salmonid catches substantially decreased at the end of June. Then sampling was conducted every other week until August 6, when sampling was terminated due to very low catches.

The site sampling attributes are fully described in Appendix A but generally, each site consisted of a gently sloping beach composed of mud, sand or gravel and free of large rocks or wood that could have posed seining obstructions.

2A.1.2 Seining Technique

The river seine (Figure 2-1) was custom made for the study and had the following dimensions:

- Two 9-meter-long wings, and one 2-meter-long central bag, totaling 20 meters in length.
- Wings that taper from 1 meter in width at the ends of the net to 2 meters in width at the bag.
- A 4.5-meter peripheral segment of each wing made of 12 mm stretched white nylon mesh. The central portions of the wings are composed of 6-mm mesh. The bag is made of 3-mm stretched mesh and dyed green.
- The net is equipped with a lead line on the bottom and enough corks to float the top line at all river depths.

A boat operator and one or two crew people deployed the net using a 15-foot aluminum skiff powered by a 60-horsepower outboard (rated 40 horsepower at the jet pump) jet-drive motor in the following steps:

1. The net was stacked onto the bow so that the lead line deployed on the downstream side of the boat, with one end was attached to the bow eye.
2. The boat was positioned perpendicular to the flow with the bow on the beach.
3. An upstream crew member held onto the unattached end of the net as it moved offshore with the motor in reverse (Figure 2-2). The downstream crew member moved 33 meters down the beach and waited for the net.
4. The upstream crew member held the net and walked downstream along the shoreline edge at the same speed as the river current while the boat continued to move away from shore perpendicular to the flow.

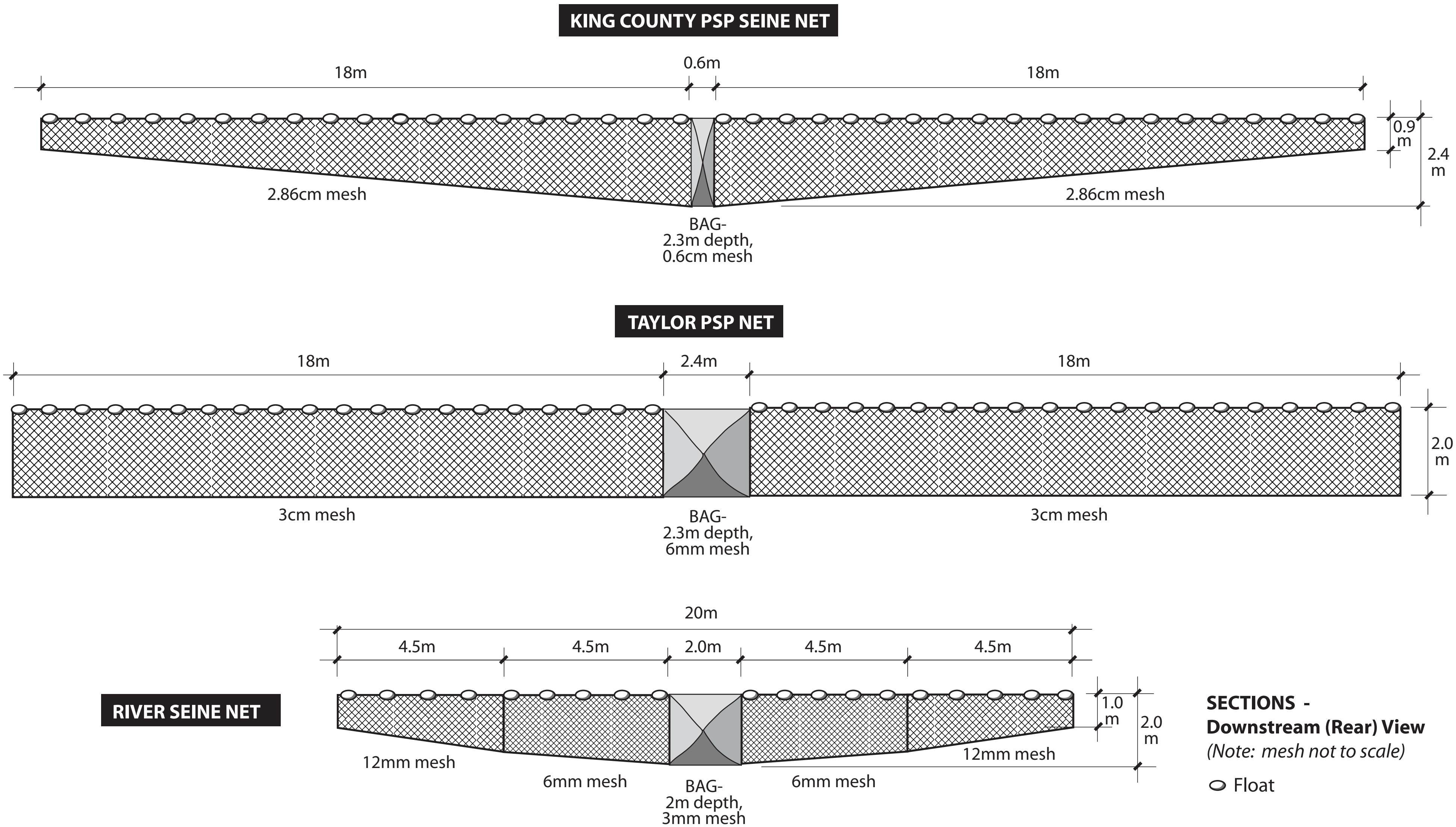

Figure 2-1. **Net plans for the 20-m River, the 36.6-m King County Puget Sound Protocol (PSP) and the 38.4-m Taylor PSP floating beach seines used in the WRIA 9 Juvenile Salmonid Survival Studies, 2001-2003.**

0 1 2 3
meters

Produced by: WLRD Visual Comm. and Web Unit
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King County
Department of Natural Resources and Parks
Water and Land Resources Division

5. When the bag was finished paying out of the boat, the boat was quickly turned downstream, with the motor still in reverse (Figure 2-3).
6. The net then payed out parallel to the water current and the boat operator tried to match or slightly exceed the speed of the current. This allowed the net to "drift" through the sampling area.
7. At a point where the operator decided it was necessary to meet the downstream crew member, the boat was quickly turned towards the beach, stern first. The bow was then brought as close to the beach as possible and the crew member waded out and prepared to disconnect the net from the bow.
8. Just before the boat contacted the river bottom, the boat operator shut off the motor and threw out an anchor on the downstream side of the boat in order to secure the boat. Then boat operator then disembarked to help the downstream crew member haul in the net.
9. The downstream crew member detached the net from the bow and quickly hauled it onto the beach. During this time, the upstream crew member continued to walk downstream, which centered the bag (allowing it to become the most downstream portion of the net) thereby forcing the fish into the smaller mesh from which they could not escape.
10. Once the downstream end of the net was brought ashore, the net was considered closed and the wings were hauled onto the beach until the bag was close to shore (Figure 2-4).
11. The bag was then held in shallow water while the crew members pinched it off from the wings and carried it back to deeper water (Figure 2-5). Taking the bag to deeper water kept the fish from becoming pinned to the substrate or any debris the net may have entrained, thereby reducing mortality.
12. Fish were dip netted out of the bag and placed into aerator-equipped five-gallon plastic buckets. These were carried to the sampling station higher up on the beach, where data were collected (Figure 2-6).

The time it took to set the net and haul it in varied with water velocity, which ranged from zero to three feet per second throughout the study and depending on the site and

Figure 2-2
River seining procedure: deploying the net.
Initiating deployment of the beach seine at upstream end of the RM 13.0 sampling site.

Figure 2-3
River seining procedure: drifting the net.
While in reverse, boat is turned parallel to flow and the net is pulled downstream slightly faster than the current speed.

Figure 2-4
River seining procedure: hauling the net.
Net is set in an upstream direction with the bag in a "centered" position.

Figure 2-5

River seining procedure: "pinching the net".

"Pinching the net" to trap the fish and collect the set.

Figure 2-6

River seining procedure: processing the sample.

Processing the set.

stage in the tidal cycle. Although individual sets were not timed, the average set (from deployment to pinching the net) generally took about five minutes. The surface area sampled remained fairly consistent. A typical set fished 33 linear meters of shoreline, with the net extending an average of 12 meters from shore, which covered a surface area of about 400 square meters. Within a given site, each sampling event consisted of three qualifying seine sets which were separated by various amounts of space and/or time, depending on the location and numbers of fish captured.

2A.1.3 Data Collection

All salmonids were identified to species; other fish were identified to species or genus, and all fish were counted. Salmonid data collection was aided by anesthetizing the fish with MS 222 (99.5 percent pure Tricaine Methanesulfonate) in about a 40 mg/l solution with the site water source. During unusually high catches of non-salmonids, the salmonids were first separated into aerated buckets and the number of other fish were counted (or in the case of large catches, merely estimated) before release directly from the net. Salmonids were checked for fin clips and the presence of coded wire tags (CWT) using a detection wand. All salmonids without adipose fin clips or coded wire tags were recorded as natural, and those with either mark were considered hatchery origin fish. Since not all hatchery fish are, marked with an adipose clip their actual numbers are somewhat underestimated in this study. The level of underestimation varied with species and time of collection (before or after hatchery release).

All natural Chinook salmon were checked for fluorescent pigment marks (application of mark described later in 2003 Methods .2) with the aid of a portable 4-watt UV lamp with a wavelength of 365 nm. The Chinook salmon were individually scanned inside a viewing box made from a 48-quart plastic cooler. The cooler remained closed during examination and had neoprene sealed arm and face holes to reduce penetration by ambient light (Fresh et al. 2003). If a mark was found, the color was noted and the quality of the spray mark rated from one to four relative to the numbers of body quadrants (nose to opercular plate, plate to middle of dorsal fin, middle of dorsal fin to caudal peduncle, caudal peduncle to tip of caudal fin) within which at least one pigment speck was found (Figure 2-7). The fish tentatively identified as marked were examined by another trained biologist for mark verification prior to permanent recording as a marked fish recovery.

The number of salmon to be measured for length data in 2003 was determined by statistically examining the fork length data for Chinook salmon sampled in 2001. It was estimated that a group of at least 35 Chinook salmon would need to be measured per week in each index site sampling event to attain a confidence limit of 95 percent or better and a power of test of 90 percent or better when comparing between sample groups. Thus a conservatively high target number for collecting Chinook subyearling fork length measurements was set at 80 natural and 80 hatchery fish per week at each index site. A goal was also set that called for sampling 35 other salmonid species for fork length. Measurements were taken to the nearest millimeter on a three-sided measuring board (Figure 2-8). The first 35 fish other than salmonids were - measured as time allowed. Salmonids whose size greatly exceeded the anticipated subyearling size range were recorded as yearlings. Length frequencies were used to determine yearlings and typically, salmonids greater than 70 mm caught before April, or greater than 100 mm caught

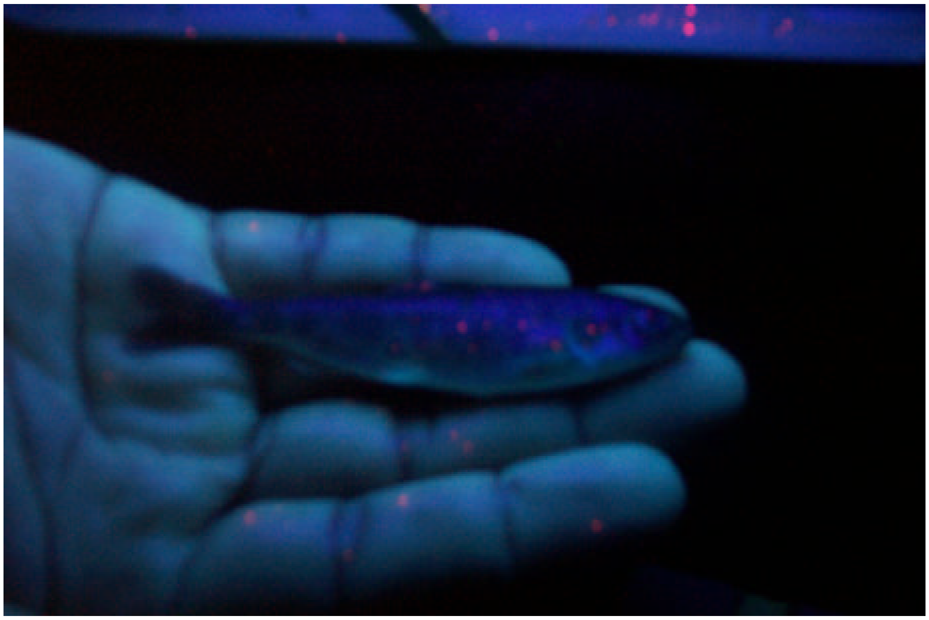

**Figure 2-7. Chinook subyearling spray marked with red fluorescent pigment and shown under ultraviolet light.
Photo courtesy of Doris Small, WDFW 2002.**

Figure 2-8. Chinook subyearling being measured for fork length. WRIA 9 Juvenile Salmonid Survival Study 2003.

Fish not intended for collection of CWT, stomach contents or otoliths were allowed to revive from the tranquilizer in aerated five-gallon buckets before release in a manner that minimized their recapture (i.e., at a sufficient distance downstream or in the same place after the last set of the seine). Any fish that was not swimming normally during release was considered an unintentional mortality and recorded as such.

Salinity, dissolved oxygen, pH and water temperature at depth were measured by deploying a portable multi-parameter YSI sonde during the sampling event. The sonde was deployed by attaching it to a connection cable and releasing it slowly from the boat into about four-meter deep water immediately offshore from the index beach.

All data for the index site sampling events were recorded on 8.5-inch by 11-inch waterproof paper data sheets and transferred into an electronic spreadsheet once per week. The efficiency of each haul was qualitatively rated as “good” or “bad.” Seine sets were rated “bad” due to problems paying out the net or snagging during retrieval, and catch data from these were not used to calculate CPUE.

2A.1.4 Salmonid Collection

Salmonids with a CWT collected at all sites in the Duwamish River and Elliott Bay were euthanized with MS 222 and preserved for CWT analysis. A maximum of five CWT specimens from each species was sacrificed in this fashion from each sampling site per week. Fish detected with a CWTs in the Green River (upstream of RM 11) were assumed to be of local origin and not sacrificed. The sacrificed fish were frozen and later transported to a WDFW laboratory for CWT extraction and identification.

Five natural and five hatchery Chinook salmon stomach content samples were collected weekly via gastric lavage (Figure 2-9) at each site under sedation with MS 222. These fish were weighed to the nearest tenth of a gram prior to lavage using a portable electronic scale. The stomach contents were placed in plastic cups and preserved with a mixture of a ten percent buffered formalin solution and an equal volume of water from the site to make an approximate five percent formalin solution in the cup. Following stomach sample collection, the fish were either retained for further specimen collection or allowed to revive and released alive. Stomach samples were also collected from up to ten chum salmon (*Oncorhynchus keta*) at each site per week, but instead of stomach lavage, chum were euthanized with MS 222 and preserved intact by placement into plastic cups containing a ten percent formalin solution. All specimens were sent to a University of Washington (UW) laboratory for analysis.

At each site, five natural and five hatchery Chinook salmon per week were selected for scale and otolith collection. These fish were euthanized with MS 222, then assigned a collection number, placed individually into labeled plastic bags and put on ice. At the end of the day the fish were frozen. At the end of the sampling season, the specimens were sent to WDFW laboratories for extracting and cataloging scales and otoliths. Otoliths were placed separately into plastic vials and cataloged at the WDFW otolith laboratory for future analysis. Scales were removed from the preferred location of salmon[1] and visually inspected for checks (tightly spaced circuli forming a distinctive mark) that could be used for life history assessment. The scales were then placed onto adhesive cards and cataloged at the WDFW laboratory. The largest appearing scale was used for measurements and counts were along the longest axis. Measurements to checks were taken to the outer edge of the last closely spaced circulus. Following extraction of scales and otoliths, the remaining body parts were placed back into the same bag and saved for future chemical uptake studies by King County staff.

[1] The preferred scale location is the area between the dorsal and adipose fin, approximately three scales above the lateral line. This is the area where scales typically form first and their shape is relatively consistent from fish to fish.

Figure 2-9 Chinook subyearling receiving gastric lavage for stomach content analysis (WRIA 9 Juvenile Salmonid Survival Study 2003).

Using the same fish for multiple samples minimized the intentional mortality of Chinook salmon. For example one fish was typically used for extraction of a coded wire tag, stomach contents, scale and otolith samples and later analysis of various chemical compounds. Additionally, unintentional mortalities were used to meet various sample targets prior to euthanizing live fish whenever practicable.

2A.2. MARK RECAPTURE STUDY

2A.2.1 Purpose

The study purpose was to monitor the behavior of discrete groups of early migrating natural Chinook juveniles (fry) from the Middle Green River (RM 64.5 to 32) to Elliott Bay. Very little is known about fry behavior or the contribution of fry to the adult population on the Green River. Using screw traps stationed at RM 34.5 on the Middle Green River and at RM 0.9 on Soos Creek, Seiler et al. (2002) were the first researchers to document large-scale natural fry migration in the Green/Duwamish watershed. Seiler et al. (2002) found that the average size of fry migration peaked in February and early March at a smaller size (average 40 mm) than the fingerlings (average 72 mm) that peak in late May and June (see introduction). The study attempted to mark as many fry as possible during their expected migration to maximize the number recaptured. A fluorescent pigment marking method was chosen that had been used previously with hatchery Chinook salmon on the Green River (Phinney et al. 1967) and more recently at Gorst Creek, WA (Fresh et al. 2003). The design of the present study called for groups of marked fish to be collected and measured to determine travel time and growth in each discrete ecotone sub-reach of the Lower Green River, Duwamish River and Elliott Bay. The present study differed from the previous Green River juvenile salmonid studies in that it was the first time natural Chinook fry were the focus. A goal of marking and releasing at least 40,000 Chinook salmon was established based on past WDFW screw trap catches at Soos Creek and the mainstem Green River at RM 34.5. Recapture effort was concentrated in areas where Chinook salmon were expected to rear, and near the boundaries of different habitat types (i.e., river to estuary to marine) in an effort to gauge the fry migration rate to as well as the approximate length of time fry spend within the various habitats.

2A.2.2 Natural Chinook Fry Collection for Pigment Spray Marking

A standard E.G. Solutions Inc. 1.5 meter-diameter, cone-shaped screw trap was placed at RM 0.9 of Soos Creek, about 100 meters upstream from the WDFW Green River Hatchery on January 29, 2003. It was anticipated that fish trapping would occur continuously until the end of the Chinook fry migration through this segment of the Soos Creek in March. This assumed ending date was based on previous data collected by WDFW staff at the same site in 2000, using the same kind of trap (Seiler et al. 2002). In 2003, trapping ended on March 28 when Chinook salmon catches at this sampling site became consistently low.

The rotating trap was suspended between two six-meter long pontoons that provide floatation for the upper half of the screw at the upstream opening (Appendix B-1a). Thus positioned, the trap fished the upper 0.9-meter of the stream water column. Steel cables were tied to trees and cement blocks on the banks to anchor the trap. The rotating screw moved fish that entered the screw opening downstream through the cone into a secure, well-aerated, water filled aluminum holding box. Fish were collected from this box using a dip net (Figure 2-10).

The trap was usually checked on a daily basis, and fish were identified and counted per the index sampling protocols. Occasionally, during days of low catches, fish were kept in the trap box for an additional day and processed as a two-day catch. Starting on February 7, a 100 Chinook salmon per week were measured to the nearest millimeter for fork length. The length measurements were paired with weight measurements to the nearest tenth of a gram, starting on February 24. Both measurements continued on a weekly basis until trapping was discontinued at Soos Creek.

In order to estimate trapping efficiency, several groups of dye-marked only or dye-marked with upper caudal fin clipped Chinook salmon were placed about 100 meters upstream to estimate trap efficiency. The dye was applied by placing the fish into an approximate 14-ppm solution of Bismark brown (phenylene-diazometaphenylene-diamine) for 45 minutes. The proportion of marked fish that were recaptured in the trap was used to approximate trapping efficiency. Due primarily to the resistance of the Chinook salmon to become obviously dyed, only one mark group of six was determined to be appropriate to use for an estimate. The screw trap recovered 18 of the 131 dye-marked and caudal fin clipped fish released on March 20, yielding approximately a 14 percent recapture rate. One of the recovered fish was captured between one and two days after release; all others were recaptured within the first 24 hours. A season efficiency estimate was not attempted due errors associated with estimation from only one sample.

Chinook salmon collected by the WDFW screw trap at RM 34.5 (Appendix B-2 and B-2a) on the Green River were also used to supplement the mark group on seven days from February 20 to March 6.

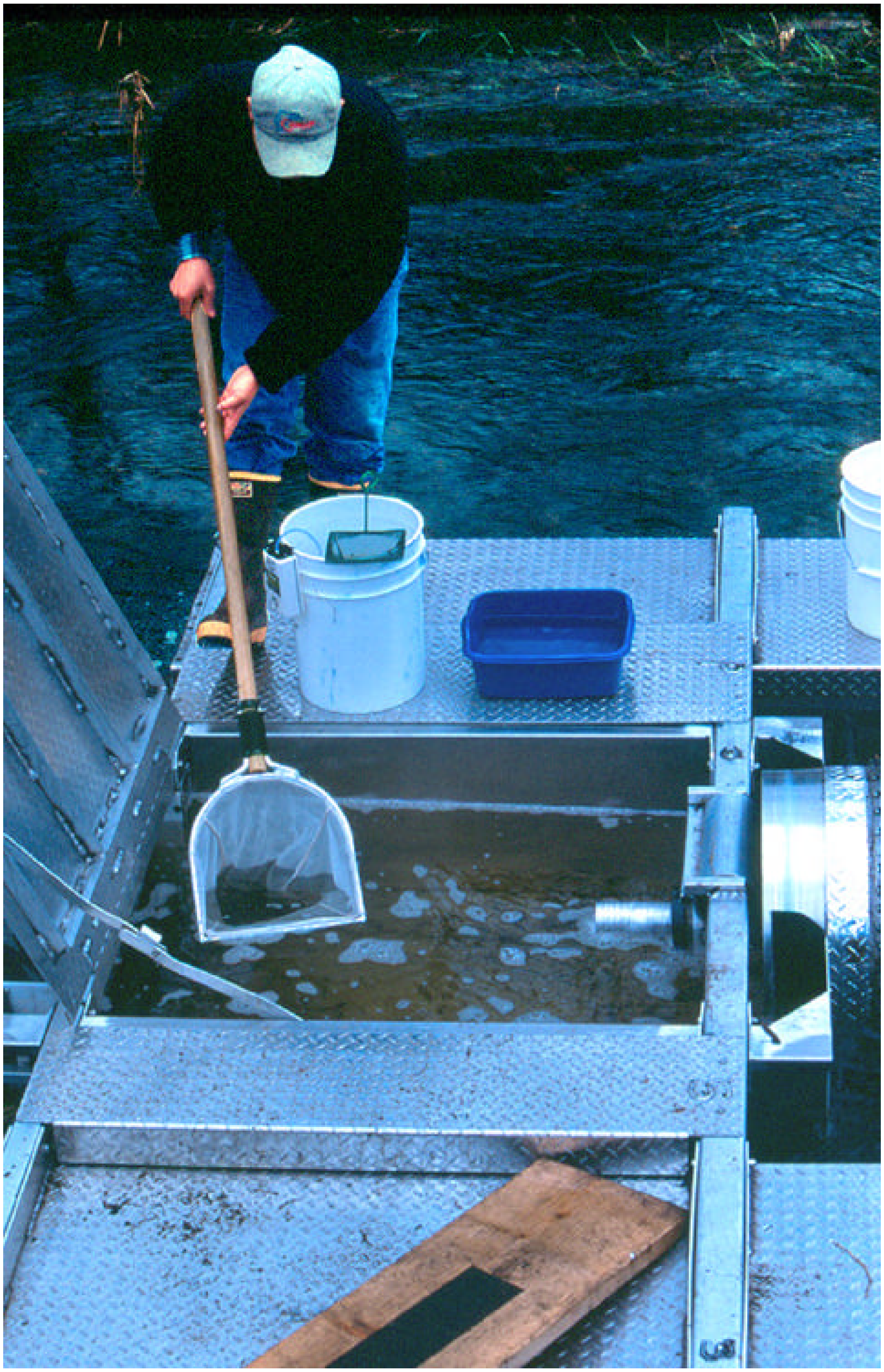

Figure 2-10 Removing natural Chinook subyearlings with dip net from trap box at Soos Creek, Spring 2003 (WRIA 9 Juvenile Salmonid Survival Study 2003).

2A.2.3 Marking

Prior to marking any natural Chinook, mark retention and mortality estimates were made using test groups of about 200 WDFW Green River Hatchery Chinook salmon that were approximately 40 mm in length**.** A variety of pigment colors, spray pressures, and spray durations were tested on February 4, 7, and 18. Mortalities that occurred within the first 24 hours after marking were assumed to be due to the marking method. The spray groups were checked on February 5 and 10 to estimate the optimal spray pressure setting and duration for mark visibility and Chinook salmon survival. The groups were again checked on April 18 and May 19 to estimate long-term retention of the mark. The early test groups were first held in hatchery troughs until they became too large, then moved to a net pen placed into the hatchery raceways after May 19.

Natural Chinook salmon marking was initiated on February 11 and on a daily basis when 600 or more fry accumulated in the trap holding box. The Chinook salmon were marked using a plastic fluorescent pigment spray per the methods described in Fresh, et al. 2003**,** although the fish in the present study were smaller (40 mm vs. 55-60 mm**)** and not reared in a hatchery. Five pigment colors (red, orange, blue, green and chartreuse) were used to distinctively mark groups of Chinook salmon according to date and collection site (Soos Creek RM 0.9, or Green River RM 34.5) groups.

About two hundred subyearling Chinook salmon were placed into the spray trough and marked during a single application (Figure 2-11). Testing resulted in a protocol of applying the pigment at an air pressure of 110 PSI from a distance of 48-cm using three, three-second duration passes of the applicator (Figure 2-12). Based on the mortality and retention study results, this procedure was estimated to produce a mark that was detectable on 83 percent of the Chinook salmon after one day, 72 percent after one week, 56 percent after two months, and 30 percent after three months, with 0.7 percent associated mortality (Table 2-2). The newly marked fish were quickly transferred into plastic aerated holding tubs using a flume, then promptly transported to downstream release points. The Soos Creek fish were released into Soos Creek about 0.1 mile downstream into a left bank pool near a hatchery raceway access bridge. Chinook salmon acquired from the WDFW trap were transported to a pool near a boat launch ramp about 0.1 mile downstream of the WDFW screw trap on the Green River (Figure 2-13). With these procedures, up to 1,200 Chinook salmon could be safely marked and released during a single spraying session. All mortalities due to marking or transporting were noted at the time of release, but additional mortality was expected to occur within 24 hours after release due to results of our mortality testing. To account for the additional mortalities and derive a season mortality estimate from the marking procedure, we applied the 0.7 mortality rate to the total number of Chinook salmon marked.

Figure 2-11. About 200 natural chinook fry (about 40 mm fork length) placed into spray trough prior to marking with chartreuse fluorescent pigment. At Soos Creek in March 2003 for the WRIA 9 Juvenile Salmonid Survival Study.

Table 2-2. 2003 WRIA 9 Juvenile Salmonid Study fluorescent pigment spray mark retention and mortality test results at Soos Creek.

24-Hour Mark Mortality Test

Date Sprayed	Date Checked	PSI (3 pass)	Color	# Chinook marked	# morts	Comments
4-Feb	5-Feb	control	control	200	0	**0% mortality in control group**
4-Feb	5-Feb	100	red	200	2	**After 24 hours, 0.7% mortality of 600 fish sprayed (4 morts)**
4-Feb	5-Feb	110	red	200	1	
4-Feb	5-Feb	90	red	200	1	

Mark Retention Tests: Various Time Intervals

# Days after marking	Mark and Check Dates	PSI	Color	# Chinook marked	% Visible mark	Comments
1	Feb 18-19	110	red	100	88%	**83% average retention after one day, 200 fish checked**
1	Feb 18-19	110	green	100	78%	
3	Feb 7-10	110	blue	199	66%	**Feb 10 average 72% retention after 3-6 days**
3	Feb 7-10	110	dark green	200	56%	
6	Feb 4-10	100	red	200	76%	
6	Feb 4-10	110	red	200	88%	
6	Feb 4-10	90	red	200	74%	
2 months	All Feb. marks - April 18	110	all		56%	**average after 2 months, 200 fish checked**
3 months	All Feb. marks - May 19	110	all		30%	**average after three months, 100 fish checked**

2A.3 RECAPTURE TECHNIQUES FOR PIGMENT SPRAY MARKED CHINOOK

Several supplemental fish sampling sites (Figure 1-1 and Table 2-1) and collection methods were utilized in order to increase the initial capture of Chinook, and subsequent recapture of pigment spray marked fish. Supplemental sampling events were both planned and opportunistic, resulting in a variety of Chinook salmon collection methods and fishing times in addition to those used in the above described Index method. The supplemental catches were processed in a similar manner as those at index sites, except that numeric targets were not established for the collection of scales, otoliths, and stomach samples. The following is a description of the supplemental fish collection methods; more information regarding habitat conditions at these sites is presented in the Appendix B.

2A.3.1 Puget Sound Protocol Beach Seine

To assist in recovering pigment spray-marked Chinook, the Port of Seattle provided the services of their consultants, Taylor and Associates, who were concurrently conducting another beach seining study, to provide additional seining effort in the Duwamish River for the JSSS. Taylor and Associates seined weekly from February 11 to March 26, and then bi-weekly from April 16 to July 25, 2003 at the Turning Basin (RM 5.5), Kellogg Island (RM 1.0), Terminal Five (West Duwamish Waterway, RM 0.0), Slip 27 (East Duwamish Waterway, RM 0.0) and Pier 90/91 (Elliott Bay). These sites are shown in Appendix B-6 and B-8 through 11. In addition to increasing the spray-mark recapture effort, Taylor and Associates also measured fish and collected fish with CWTs, providing additional 2003 data for the present report.

The net used was larger than the river seine described above, and was named the "Puget Sound Protocol" (PSP) net because its dimensions were identical to those used in previous sampling fish studies conducted in the nearshore by Simenstadt (1991). The PSP net has two wings that are each 18 meters long, 2.4 meters high, and made of 3-cm mesh. At the center of the net, the wings connect to a 2-meter-high, 2.4-meter-wide, 2.3-meter-deep bag of 6-mm mesh.

The net was deployed parallel to the beach by a boat which motored slowly 20 to 30 meters from the shore. Following deployment, both ends were hauled in and drawn together by two or more people stationed on shore using 33-meter lines attached to the wing ends (Figure 2-14). After approximately one third of the length of the net was pulled in toward the to shore, the ends were drawn closer together to corral the fish. Once the ends were brought to shore, they were steadily pulled further in order to force the fish into the bag. Four or more people were usually needed to effectively operate the PSP net and process the catch. Fished in this manner, the PSP net covered about 500 square meters of surface area. The net was used at various low velocity Duwamish River and Elliott Bay sites, but was found to be ineffective in swift currents or in confined areas within the Green River.

Occasionally, the JSSS used a smaller PSPknjk net with slightly different dimensions but deployed it in the same manner. The main difference between the standard and smaller PSP nets is that the smaller PSP had wings that tapered to 0.9 meters on the ends, and the bag was about one half the width of the standard PSP net.

2A.3.2 Kent Screw Trap

On May 8, 2003, the screw trap was removed from Soos Creek and placed in the Green River at RM 18 in the City of Kent. The trap was anchored onto the 212th Street Bridge abutments using cables and lines (Appendix B-3a). Flow velocity at the Kent site averaged about four feet per second. The trap operated from Monday morning to Friday afternoon during the juvenile salmonid outmigration period. The trap was removed on June 26 when fish catches diminished. The trap was accessed by crew members aboard a 12-foot aluminum skiff and catch was processed at least once per day. Two Bismark brown dye-marked groups of Chinook salmon were used to estimate trap efficiency in a similar fashion as the trapping efficiency study conducted on Soos Creek. On June 10, sixteen marked Chinook salmon were released at the Van Doren Landing Park boat launch at RM 19, about one mile upstream from the Kent trap. On June 11, forty-five were released about 400 meters upstream of the trap on the right bank. Of these 61 total fish released, three were recovered with obvious dye marks on June 12, yielding a five percent recapture rate while the river was flowing between 641 and 663 cfs. Efficiency of the trap to estimate total daily migration was not applied due to the small sample size.

Figure 2-14 Pulling in the bag of a beach seine with similar dimensions as the "Puget Sound Protocol" net used in the WRIA 9 Juvenile Salmonid Survival Study 2002 and 2003.
The photo is reproduced courtesy of Doris Small, WDFW.

2A.3.3 Onieda Trap Net

The same Onieda trap net used in a previous Port of Seattle fisheries study in the Duwamish River (Weitkamp 1982**)** was set in a bight on the east side of Kellogg Island from February 6 to June 12, 2003 (Figure 2-15). The trap box was a two-meter cube with an inverted cone entry made of 4.8 mm-stretched mesh. A zippered top was added to the original trap box during the study to prevent fish from escaping and deter avian predation. Fish were led to the box by two 42-foot-long wing nets and a center lead net that extended to the high tide line (Appendix B-8a). The waterward end of the trap box was anchored using an existing pile driven at –2.5 elevation (MLLW=0.0). A sliding mechanism was devised that allowed the box to move up and down within the locally prevailing five-meter tidal elevation range. This was accomplished by attaching a 3.2-meter long, 5.1-cm-diameter aluminum pipe to the pile with bolts and 10 cm. spacers. A 20-cm-diameter stainless steel ring was placed over the pipe prior to fastening. The box end of the trap would then clip onto the ring allowing the box to move freely up and down with the tide. The center lead net was then tied to a fixed structure on the bank, and the trap wings were anchored close to high tide line, which allowed enough scope to accommodate the tidally influenced change in surface water elevation. The net was typically set on Tuesday and taken in on Friday after 72 hours of continuous fishing. The trap was not set during times when the tidal elevation was less than 0.0 (MLLW), because during such conditions, the net rested on the bed in less than 1.5 meters of water, creating a stranding hazard for the trapped fish. The trap box was emptied daily by unclipping it from the anchor ring and hauling it to shore for catch processing. After processing the catch, the trap was towed back to the pile by boat and reattached. In early June, two river otter were observed exiting the hold box of the Onieda net, and the net was dismantled shortly thereafter to prevent further fish mortalities. It was possible that the otters had substantially reduced the catch throughout the season.

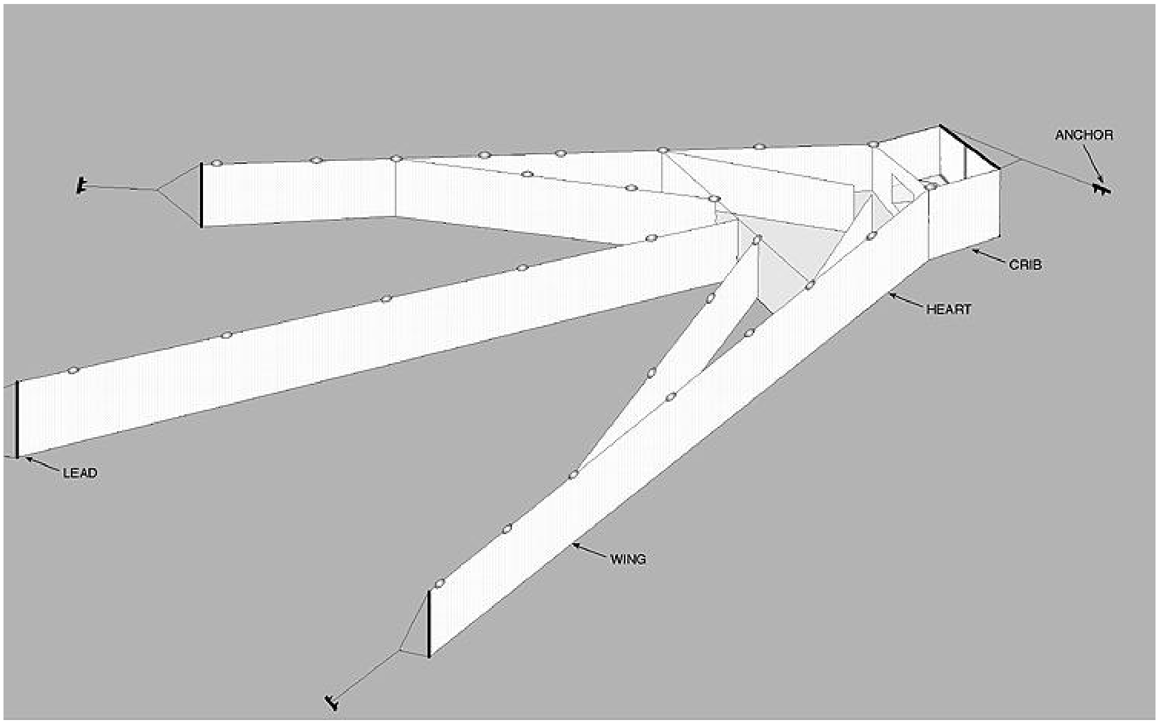

Figure 2-15 Onieda trap net design used on the east side of Kellogg Island for the WRIA 9 Juvenile Salmonid Survival Study in 2003. The same net was used during a Duwamish River fisheries study by the Port of Seattle in 1980 (Wietkamp, 1982). The figure is reproduced courtesy of Don Wietkamp, Parametrix Inc.

2A.3.4 Fyke Nets

Two 1.3-meter-high nylon fyke nets with 10-meter-long wings of 6 mm stretched mesh were set using rebar stakes near Green River at RM 13 in Tukwila. One fyke net was placed on the left bank about 30 meters upstream near the Marriott Hotel (Figure B-4a), and the other was placed immediately upstream of the Best Western beach (Figure B-4b) on the right bank (Appendix B-4b). These nets were set intermittently when river flows were less than 2,000 cfs from February 19 to May 2, 2003, and were checked for fish and cleaned on a daily basis. These nets worked best when placed along the banks or near eddies where flow velocity was considerably less than that in the main channel (i.e., 1 to 2 fps vs. 3 fps).

2A.3.5 Baited Pots

Up to six 1-meter-long by 0.3-meter-diameter pots made of 6 mm galvanized wire mesh were baited with cat food, placed along the shoreline and tied off to sturdy vegetation at various locations near the Best Western and Marriott sites (Appendix AM-5) in March and April. The pots were found ineffective for capturing Chinook salmon since the fish were small enough (less than 50-mm fork length) to easily escape through the 6-mm openings in the mesh.

2A.4 DATA ANALYSIS

Most catch and size data were organized and reported by statistical week. In this report, statistical weeks began on Sunday and ended on Saturday. Thus statistical week 1 began on January 1 and ended on the next Saturday, and therefore was less than seven days. Subsequent weeks were numbered chronologically through the end of the year. Days corresponding to statistical weeks during each year can be viewed in the appendix or on the Alaska Department of Fish and Game website:

http://tagotoweb.adfg.state.ak.us/CWT/reports/sbp_calendar.asp?value=statweek

Catch and size data were typically reported as weekly mean values ± 1 standard deviation. CPUE values were calculated for the index sites only and the combined index and supplemental beach seine data. When combining index beach seine catch data (i.e., stemming from use of the river seine) with supplemental catch data collected using the larger PSP beach seine, the catch rates of the two gear types were standardized before calculation of a geometric mean. Comparison of river seine and the PSP seine catches made at the same location and week indicated that the PSP net captured twice as many subyearling Chinook, on average, as the river seine (two factor ANOVA: week and gear type; df = 1, 10, 277; $F = 5.33$; $P = 0.022$). Thus, PSP catches of Chinook salmon were multiplied by 0.5 in order to make them comparable to the river seine catches (see Appendix for statistics details). When combining standardized catch data from the two beach seines (river and PSP), we calculated the geometric mean[2] so that seasonal trends in catch rates from one site to another would be less influenced by single large catches.

Some statistical analyses were conducted to test specific questions. Regression analysis was used to determine correlation between two variables. Analysis of variance (ANOVA) was used to test for differences in mean values. These are basic statistical tools that are described in most statistics books (e.g., Zar 1996). A key term that describes the statistical significance of a test is the P value. Typically, a P value < 0.05 implies statistical significance, i.e., the null hypothesis is rejected and the values are statistically different (ANOVA) or two data series were correlated (slope of a regression was >0). The P value indicates the probability of rejecting a null hypothesis when in fact it should not have been rejected (i.e., no difference between two values).

2B. 2002

The primary JSSS objective in 2002 was to define the time range of natural and hatchery juvenile Chinook salmon outmigration in the Green/Duwamish River by collecting the fish with a seine net. Seining also afforded an opportunity to collect information regarding changes in salmonid size and abundance over the outmigration season. The JSSS also supported two separate juvenile salmonid tracking feasibility studies. The first used acoustic tags and the other passive-integrated-transponder (PIT) tags, to track fish movement during outmigration. These two pilot studies were initiated to evaluate independent methods that could potentially be used to confirm Chinook salmon growth and migration estimates developed as an outcome of the seining study.

[2] A geometric mean is commonly used as a measure of central tendency for fish catch rates because fish catches tend to be log-normal distributed (i.e., many small catches and few very large catches) and the arithmetic mean tends to overestimate central tendency.

2B.1 SITES AND SCHEDULE

Three sites were selected for consistent seining during the 2002 study: Best Western (RM 13), Trimaran (RM 6.5) and Kellogg Island (RM 1). The locations and physical description of the sites are given in the 2003 section of the methods, Figure 1-1, Appendix B and Table 2-1. Since this was the first JSSS attempt at seining in the Duwamish estuary, seining methods were not as standardized as those used at the 2003 Index sites. The Best Western site was selected to investigate migration timing as Chinook salmon left the Lower Green River and entered the Duwamish estuary. The Trimaran and Kellogg Island sites were used to estimate the duration of Chinook salmon residence in the estuary prior to migration to the Puget Sound. In addition, information collected at the WDFW screw trap at RM 34.5 was used to estimate migration timing as Chinook salmon left the Middle Green River and entered the Lower Green River, and size range of natural Chinook salmon that originated in upstream spawning areas.

Seining began on January 30 and continued on approximately a weekly basis until July 18 when catches greatly decreased, then sampling proceeded on an every other week schedule until regular sampling was halted on September 12, 2002 due to very low catches. One final seine-sampling event occurred on November 18 after a fall freshet to determine if any Chinook salmon residing in the river over the summer may have outmigrated late in the year. Seining at Best Western ended on August 15 when Green River flows diminished to a level (240 cfs) that precluded access by boat.

2B.2 SEINING TECHNIQUE

The previously described 2003 river seine method was used at the Best Western sampling site, and a combination of the river seine and modified PSP methods were used at the Trimaran and Kellogg Island sites in 2002. Due to seining obstructions at the Trimaran and Kellogg Island sites, it was necessary at times to either shorten the distance from shore or the length that the PSP net fished, or use the river seine instead of the PSP net. In June 2002, when salmonid and shiner perch catches were high, the river seine was typically used since it was able to safely capture manageable numbers of fish and avoid the over crowding and stressing the fish in the net bag, which tended to occur using the PSP net.

2B.3 DATA COLLECTION

Data were collected in 2002 in a similar manner to that described in the 2003 section of this report, with the following differences:

(1) Chinook salmon were not marked with fluorescent pigment in 2002 so they were not checked for that mark.

(2) Scale, otolith and gut samples were not taken.

Chinook salmon were not consistently checked for CWTs due to intermittent availability of the detector.

Weekly numerical targets were not set for fish sample size; instead, usually all Chinook salmon were measured and all other fish were counted and measured only as time allowed.

Water quality parameters were not sampled with the YSI sonde.

2B.4. YEARLING CHINOOK SALMON ACOUSTIC TAG TRACKING PILOT STUDY

A pilot study was conducted by King County staff to acoustically track the outmigration of hatchery reared yearling Chinook salmon from the WDFW Icy Creek rearing facility. The confluence of Icy Creek (believed to be the spring outlet of Fish Lake WRIA 09.0126) is located on the left bank of the Green River at RM 48.4 (Figure 1-1). The objective of this pilot study was to assess the feasibility of monitoring the migration of yearling Chinook salmon with hydroacoustic tags on the Green/Duwamish River and along the Puget Sound nearshore in and near Elliott Bay. The 9 x 20 mm Vemco V8SCL-6L tag was used. This tag is usually not recommended for use in salmon less than 250 mm in fork length (about 10% of body mass) because of the interference with food digestion (displacing too much stomach volume) and swimming ability of the smaller fish. Most Green River yearling hatchery Chinook salmon are less than 250 mm in fork length and subyearlings are typically even smaller than 100 mm. Nonetheless, the Vemco V8SCL-6L tag was used because it was the smallest transmitter available.

On May 22, two acoustic tags with two-second period signal settings were surgically implanted into yearling hatchery Chinook salmon from the Icy Creek rearing facility. A 72kH signal transmitter was implanted into a 207-mm fork length fish and a 75kH transmitter into a 198-mm long Chinook. The fish were monitored for 24 hours, and recovered very well during this period. Following the 24-hour recovery period they were released into the Icy Creek rearing ponds on May 23. The transmitters were tested and deemed operable based on positive signals detected while the fish were in the ponds. The pond gates were opened allowing free access to the Green River, and the fish were determined to have left the ponds between 3:30 PM, May 23, and 9:00 AM the next morning.

2B.5. SUBYEARLING CHINOOK SALMON PASSIVE INTEGRATED TRANSPONDERS (PIT) TAG MIGRATION PILOT STUDY

King County staff also teamed up with United States Army Corps of Engineers (USACOE) staff to track the migration and growth of subyearling Chinook. Chinook salmon were PIT-tagged and released at the WDFW screw trap on the Green River mainstem and at the Green River Hatchery at Soos Creek from June 7 to September 12, 2002. This pilot study was undertaken in order to determine the level of effort needed to recover PIT-tagged fish in the Green/Duwamish River prior to full implementation of this tracking method. A goal was established of releasing a total of 5,000 PIT-tagged hatchery and natural Chinook salmon during this pilot study. Full details are presented in Appendix C, (Goetz 2003) and in Appendix C.

King County staff also coordinated with the WDFW staff to implant the tags and provided some of the equipment and labor used in recovering the PIT-tagged fish. This extra effort was concentrated between June 9 and June 21, and included night seining at the Best Western site and daytime seining in the Duwamish River. The river seine method was used to collect Chinook salmon during this study, and the Chinook salmon catch was passed through a Biomark FS200IF racket PIT tag reader (Figure 2-16) to test for the presence of tags. After release of the PIT-tagged fish, on June 7, all Chinook salmon captured during the weekly seining events were also passed through the reader. Any positive readings were recorded electronically by the detector and in written notes.

Figure 2-16. Crew sampling Chinook salmon for PIT-tags on the Green River at Best Western Beach during June 2002 (WRIA 9 Juvenile Salmonid Survival Study).

2C. 2001

The primary objective for the 2001 study was to establish an effective collection site for Chinook salmon juveniles in a location representative of their migration timing and size prior to entering the Duwamish River estuary. The study was considered a pilot since standard methods for collecting fish in the Lower Green River needed to be developed. Collecting a baseline of Chinook salmon and other salmon size, migration timing and differences between natural and hatchery origin was also an objective assuming the first could be met.

2C.1 FISH COLLECTION ALTERNATIVES

River seining was selected as the most appropriate method to collect Chinook salmon near the downstream end of the Lower Green River. Seines were used successfully in the Green/Duwamish River by others (Appendix A) to capture fish with minimal mortality.

Three other methods considered but rejected were placement of a screw trap similar to the one used by WDFW at RM 34.5, an inclined plane trap, and electrofishing. Originally the screw trap was thought to be a preferred method but subsequent field investigations found that flow conditions in the Lower Green River frequently do not meet a minimum flow velocity criterion. WDFW staff recommended a minimum flow velocity of six feet per second based on the swimming speed of juvenile salmonids. It was assumed that salmon greater than 100 mm in length could avoid the trap and thereby bias the catch data (WDF 1991). The inclined plane trap, another type of floating trap, is even more dependent on high flow velocity to capture fish; therefore it was also deemed unsuitable. Electrofishing in the main river channel would have required powerful boat-mounted electrofishing equipment that was cost prohibitive for the project and also was considered to pose too much of a fish mortality risk.

2C.2 SITE SELECTION CRITERIA

The criteria for site selection were: (1) accessibility by boat during most flow conditions; (2) location within the lower end of the Lower Green River; (3) continual downstream flow at all tidal elevations and river discharges to avoid recapture of previously sampled fish; and (4) presence of a beach large enough to allow the crew to haul in a seine net.

A reconnaissance trip from RM 2.0 to 23.3 was made on March 20, 2001 to search for feasible seining sites. One site, located on the right bank at RM 12.7, met all four of the above criteria. The site is adjacent to the Best Western Motel in Tukwila, Washington and is shown in Appendix B-4b. This site contains an approximately 100-meter-long, gently sloping beach on the inside of a river meander bend. The beach and the adjacent streambed are composed primarily of sand with some loose peat and coal deposits, small woody debris, and occasional refuse (golf balls, beverage cans, broken glass, etc.). The banks are about 80 meters apart at the top of bank, and both are composed of engineered rock revetments covered with blackberry and sparse willows growing near the toes of the revetments. The streambed follows a fairly consistent slope of about 1-meter vertical drop to every 20 meters horizontal in the upstream half of the seine site. At the midpoint of the site, a sand bar is usually present, and a hole at least 2 meters deep forms immediately downstream along the right bank. This hole typically fills with sand during high river discharge (i.e., approximately 3,000 cfs and greater) and gradually reforms when flows recede.

2C.3 SAMPLING FREQUENCY

The site was sampled during daytime hours once per week from May 8 to July 10, 2001. Between June 5 and 6, the site was also sampled at night to assess the outmigration rate during a 24-hour period judged to approximately coincide with the peak of the juvenile outmigration period. After July 10, when migrant capture numbers had substantially decreased, the site was sampled every other week until August 23, when the study was terminated. This schedule resulted in the site being sampled on 14 separate occasions in 2001. Hauls were spaced at least one half-hour apart to allow fish to overcome behavioral disturbance caused by sampling activities prior to the next haul.

2C.4 SEINING TECHNIQUE AND DATA COLLECTION

The River Seine previously described in the 2003 Methods was first developed and used in the 2001 study. Data collection methods was also similar to those described in the 2003 Index Site Seining Methods with the following differences:

1. Chinook salmon were not marked with fluorescent pigment in 2001 so they were not checked for that mark.
2. Fish were not collected.
3. Chinook salmon were not checked for presence of CWTs.
4. Weekly numerical targets were not set for fish sample size; instead, all Chinook salmon were usually measured and all other fish were counted and measured only as time allowed.
5. Water quality parameters were not sampled with the YSI sonde.

CHAPTER 3. RESULTS AND DISCUSSION

3.1 TEMPERATURE, SALINITY, AND RIVER FLOW

3.1.1 Temperature

Daily water temperature was recorded continuously at RM 35 from July 20, 2001 to September 30, 2003 (Taylor Associates and King County 2003). During December through early March of water years 2002 and 2003 (e.g., October 2001 to September 2003), the trend in temperature was flat while fluctuating about a mean temperature of 6°C (Figure 3-1). Most Chinook salmon are embryos in the gravel during this period. Mean daily temperature began to increase in early March, peaked in mid-July or early August at 18°–20°C, then declined in September and October.

Water temperature in 2002 was considerably lower than that in 2003 (Figure 3-1). In March, when temperature initially began to increase and many Chinook fry were present (see below), daily mean temperature averaged 3.3°C less in 2002 than in 2003. Below average temperatures continued throughout spring and early summer of 2002, averaging 2.9°C less in June when many Chinook fingerlings moved into marine waters. As shown below, growth rate of juvenile Chinook salmon was less in 2002 than in 2003, possibly because of cooler water temperatures.

River water temperature at RM 35 varied considerably on a diel basis, reflecting the rapid response of river water to changes in air temperature. The daily range in temperature was relatively small during the winter and early spring of 2003 (typically <1°C), but it increased to approximately 3°C in May, and up to 6°C in June, when juvenile Chinook salmon were still present (Figure 3-1). Daily fluctuations in temperature remained high during July and August of 2003, when adult Chinook salmon begin to enter the estuary and lower river, then declined to <3.6°C in September, when adult Chinook salmon typically begin to migrate upriver.

Daily mean water temperature at RM 35 and RM 19 were highly correlated during 2003, as expected (Figure 3-2). However, temperature was typically warmer at RM 19, averaging 0.5°C higher during March and April, 0.9°C higher in May and June, 1.2°C higher in July and August, and 0.6°C higher in September.

Water temperature was measured in grab samples taken periodically in the Duwamish estuary during 2000 through 2003. Peak surface water temperature measured at RM 4 reached 21.2°C in late July (Figure 3-3). Peak surface water temperature measured at RM 0.2 was typically several degrees lower than water temperature measured at RM 4, e.g., 18.3°C in late July 2003, due to the effects of mixing with the cool marine water of Elliott Bay. Water temperatures near the dredged channel bottom were also typically several degrees cooler than surface temperatures during summer, but bottom temperatures were typically warmer during the winter. Temperatures throughout the water column tended to be similar during spring.

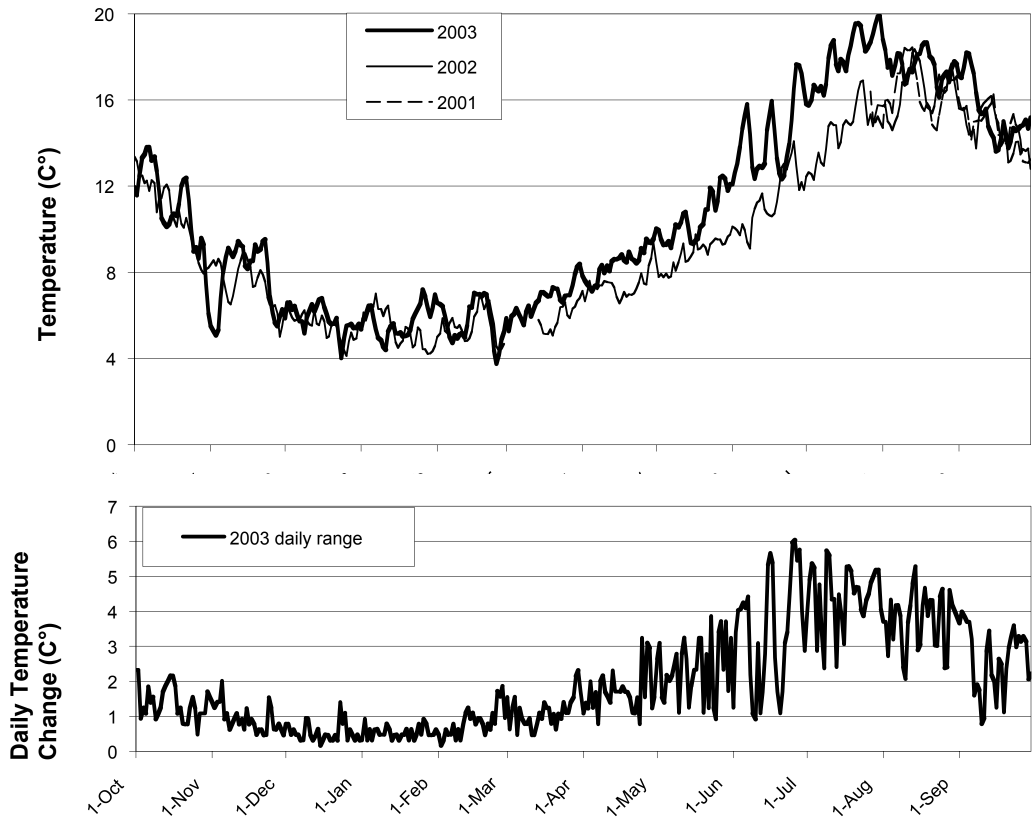

Figure 3-1. Mean daily water temperature (C°) of the Green River near RM 35, July 20, 2001 to September 30, 2003 (upper graph). Daily range in temperature during 2003 is shown in lower graph. Data shown by water year, October through September

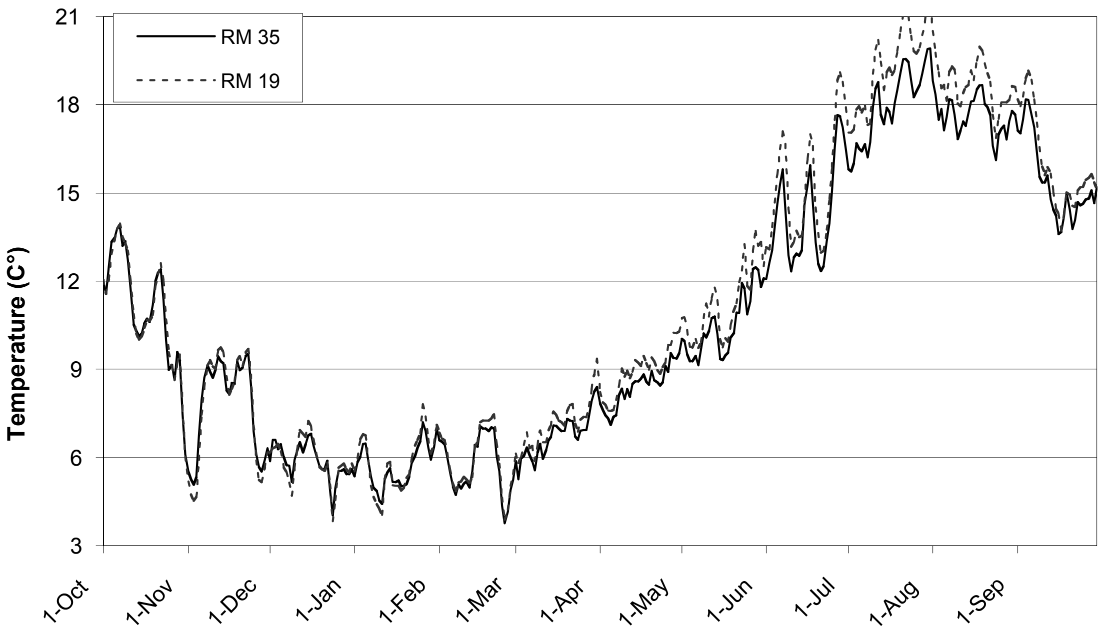

Figure 3-2. Comparison of mean daily surface water temperature at RM 35 and RM 19 from October 2002 to September 2003.

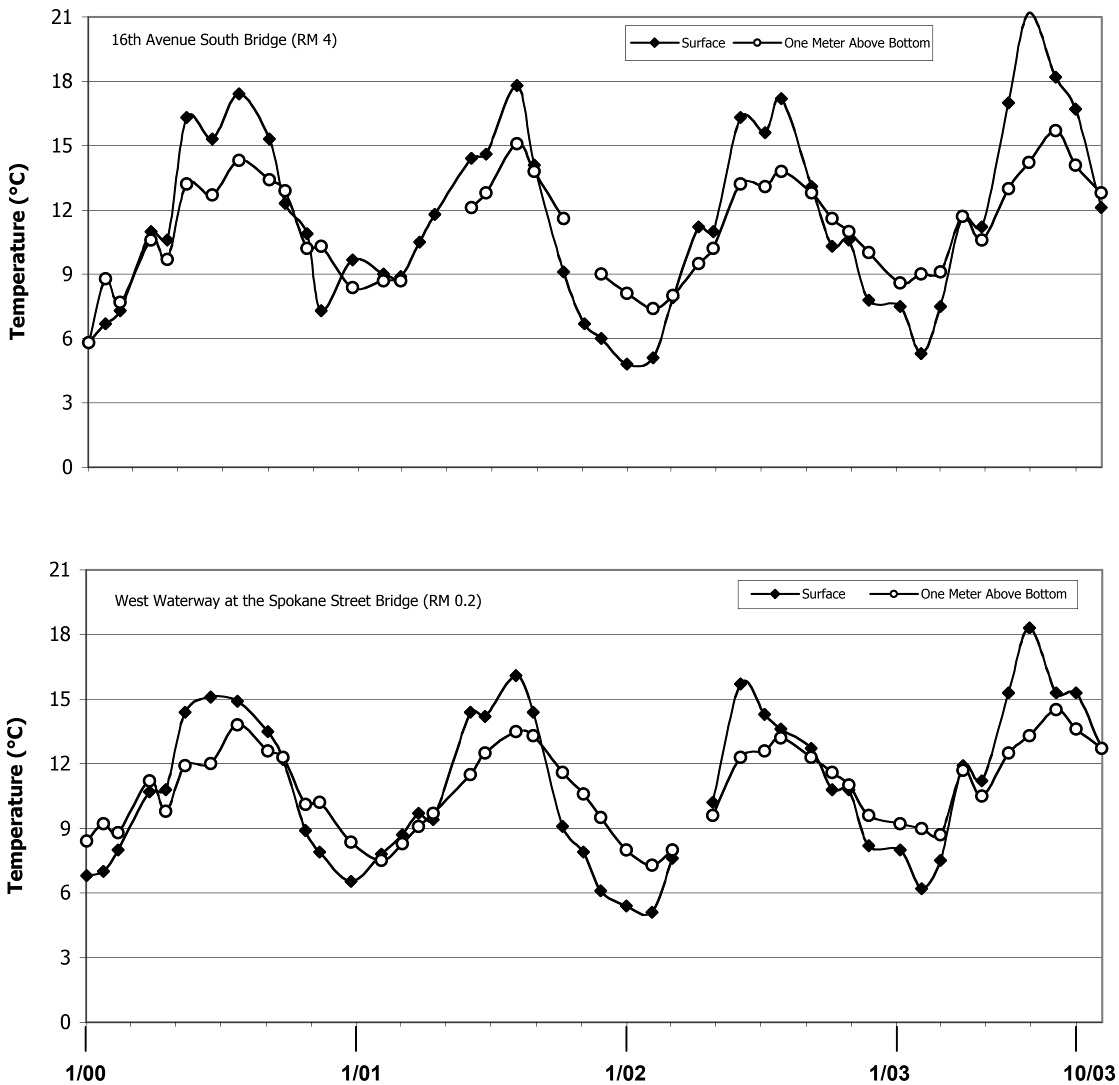

Figure 3-3. Water temperature in the Duwamish at RM 4 (upper graph) and RM 0.2 (lower graph), January 2000 to October 2003. Values based on grab samples from near surface and near bottom. Data source: King County 2003.

3.1.2 Salinity

Grab samples were measured for salinity periodically in the Duwamish estuary during 2000 through 2003. At RM 0.2 and RM 4 (Figure 1-1), salinity near the bottom of the dredged channel was typically 27-31 ppt and 24-29 ppt, respectively (Figure 3-4). Slight decreases in bottom salinity occurred at RM 4 during spring, reflecting increased river flow.

Surface salinity was strongly influenced by river flow. At RM 4, surface salinity was typically low during winter and spring when flow was high (~5–10 ppt at RM 0.2, ~1–3 ppt at RM 4), and high during late summer and fall when flows were low (~15–25 ppt at RM 0.2, ~1–15 ppt at RM 4).

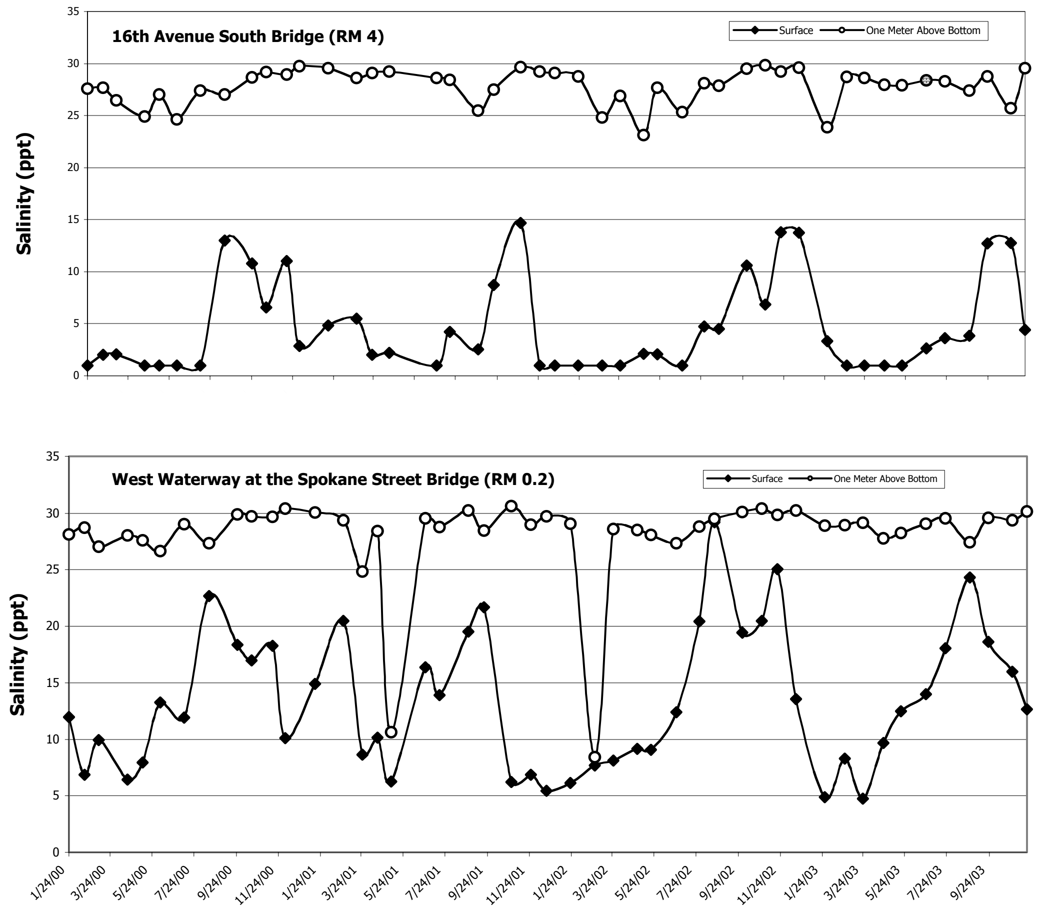

Figure 3-4. Salinity in the Duwamish at RM 4 (upper graph) and RM 0.2 (lower graph), January 2000 to October 2003. Values based on grab samples within 1 m of surface and bottom (King County 2003).

3.1.3 River Flow

Mean monthly flow recorded near Auburn during the period following construction of Howard Hanson Dam, 1962-2003, was typically high from December through February (2,200 cfs), then declined slightly in March (1,700 cfs), April, (1,800 cfs) and May (1,600 cfs) (Figure 3-5). Starting in June, flow declined sharply (1,000 cfs) through August (310 cfs), the month with the lowest flow, and remained relatively low until November (1,600 cfs).

Peak daily flows during winter can affect salmon survival because high flows can scour redds when embryos are in the gravel, or force small emergent fry to travel rapidly downstream into sub-optimal habitats. Mean daily flow of the Green River near Auburn in the period from 2001 to 2003 exhibited sharp spikes of up to 8,200 cfs during November through April (Figure 3-5). Maximum daily flow during the winter (November to March) was exceptionally low in 2001 (2,220 cfs), compared with 2002 (6,790 cfs), and 2003 (8,184 cfs), suggesting that winter flows in 2001 were more conducive to high salmon survival than flows in the following two years.

Mean daily flow during November through March 2001 was exceptionally low—(59 percent below the long-term mean). Flows during this winter period were also 26 percent below average in 2000 and 22 percent below average in 2003 but were slightly above average (three percent) in 2002. Flow in 2002 remained = above (46 percent) the long-term mean during April though July, but was exceptionally low (-71 percent) during October through December 2002.

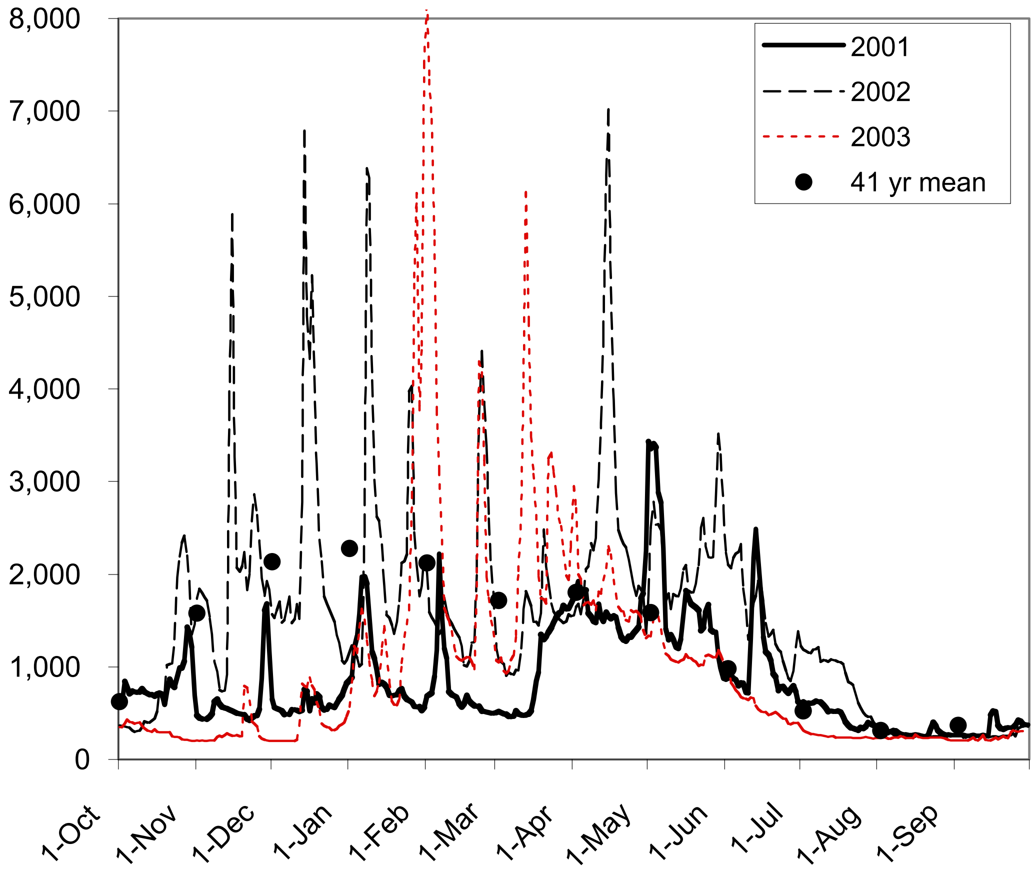

Figure 3-5 Mean daily discharge of the Green River (Auburn gage 12113000) during 2001, 2002, and 2003. Mean monthly flow during 1962-2003 (post Howard Hanson dam) is shown for comparison. Water year begins October 1.

3.1.4 Sample Site Water Salinity, DO, Temp (to be included in final)

3.2 OVERVIEW OF SAMPLING EFFORT IN 2001, 2002, AND 2003

During the three years of study, 59,952 subyearling Chinook salmon were captured during 1,150 beach seine sets and 168 days of trap use as shown in Table 3-1. Approximately 65 percent of the seining effort and 100 percent of the trapping effort occurred in 2003. In 2003 screw traps placed in Soos Creek and in the Green River at RM 18 in Kent (RM 18) fished for a combined total of 89 days, and accounted for 77 percent of the three-year total catch of subyearling Chinook salmon. Details of sampling effort by method are provided in Appendix D (Appendix Tables 1, 2, 3, and 4).

Table 3-1. Sampling effort and subyearling Chinook salmon catch totals, 2001-2003.

	Beach Seine				Traps	
	# Sets	percent total	# Chinook	percent total	Days	# Chinook
2003	742	65 percent	8119	63 percent	168	46,981
2002	330	29 percent	2745	21 percent	0	0
2001	78	7 percent	2107	16 percent	0	0
Totals	1150		12971		168	46,981

3.2.1 Species Catch Composition in 2003, 2002 and 2001

Chinook and chum salmon were consistently among the top three of the most numerous species captured at sites within each of three major sampling areas: the Green River, the Duwamish estuary and Elliott Bay (see below). Salmonids dominated the Green River catches and Chinook salmon were the most numerous of all fish species captured. Chum salmon outnumbered all other species in the 2003 Duwamish River catch, and were outnumbered by shiner perch in 2002. Numbers of species were greatest in the Duwamish River and lowest in the Green River. Appendix D (Appendix D, Tables 8–13) contains yearly catch data by species or genus, age, origin (hatchery or natural), and site. Although the fish collected by Taylor Associates in 2003 supplemented the mark recovery effort and estimates of catch per unit effort at various sites these catch data are not included in the species catch composition of this report in order to avoid double reporting of captured species. Those fish will be enumerated in a separate report prepared by Taylor Associates for the Port of Seattle.

Table 3-2. Catches of the three most numerous species and total numbers of species captured in the mainstem Green River, Duwamish River, and Elliott Bay, 2001-2003.

		Chinook*	chum	Coho*	shiner perch	dace	mountain whitefish	3-spine stickle-back	number of species
2003	Green River**	2054	602	452					12
	Duwamish River	4664	20,811		5868				24
	Elliott Bay	373	3233		216				17
2002	Green River	613				61		263	14
	Duwamish River	1801	2612		5680				18
2001	Green River	2223	237				79		11

*Includes subyearlings, yearlings, hatchery and natural fish.

**Excludes Soos Creek screw trap catches.

3.2.2 Fish Measurements in 2003, 2002 and 2001

Fork length measurements were made of 7,551 subyearling hatchery and natural Chinook salmon during the three-year study. Lengths of other species were also measured. Appendix D (Appendix Tables 14–37) provides weekly fork length measurements of natural, hatchery, subyearling and yearling Chinook salmon by location during 2001, 2003 and. These data are made available for comparison with data collected in future studies.

3.3 YEAR 2003 CHINOOK SALMON ABUNDANCE AND MIGRATION TIMING

The WDFW screw trap at RM 34.5 captured natural juvenile salmon that were actively and passively moving downstream with the current from spawning areas further upstream and nearby in the Middle Green River. The trap provided a weekly index of abundance of juvenile Chinook salmon moving into the Lower Green River from early February through late July 2003. In the Lower Green River, the Duwamish estuary and nearshore marine areas, a river beach seine (see methodology for description) was used to sample relative abundance of juvenile salmon on a weekly basis at the key index areas and in accordance with the schedule described in Methods section of this report (Figure 2-1). Sampling of these index sites in 2003 occurred weekly from mid-January through early August. Data from additional sampling occurred less regularly at RM 18, RM 5.5, RM 4, and RM 0 and were not included in the index catch statistics.

3.3.1 Natural Subyearling Chinook Salmon

At the RM 34.5 trap, natural subyearling Chinook salmon were relatively abundant from the beginning of sampling in early February through late March (Figure 3-6). Peak catches of juvenile Chinook salmon (~700 Chinook salmon per day) occurred during early March. Catches were exceptionally low from April through mid-May, averaging 14 per day, then increased slightly during late May through mid-June, when a 45 Chinook salmon per day were caught. Catches declined to fewer than 5 fish per day during late June and July. A bimodal pattern of juvenile Chinook salmon migration has been described in other Northwest rivers (Healey 1991), but it was especially weak in the Green River during 2003.

The relatively large migration of natural subyearling Chinook fry observed in catches at the RM 34.5 screw trap during late winter was also observed in the estuarine transition zone at RM 6.5, where peak weekly catches reached up to 70 fish per beach seine set from mid-February 16 through early March (Figure 3-6). During this period, above average catches also occurred at index sampling sites near Kellogg Island (RM 1) and in Elliott Bay (Seacrest: one sample period), although sampling at these sites was less frequent compared with that conducted at RM 13 and RM 6.5, and catches were considerably smaller.

These relatively high catches in the Duwamish River during the late winter were not reported in any of the previous Green/Duwamish studies (Appendix A), although very few sampled in the winter. Warner and Fritz (1995) seined RM 6.5 and other Duwamish sites in 1994 from February to September but found low concentrations of Chinook salmon until a peak arrived in May coinciding with the release of hatchery Chinook. Flows during February through June 1994 were 31% lower than normal with no severe flooding and a spring peak of 4,200 cfs on March 3. Although the high concentration of juveniles during late 2003 winter was unexpected by many local biologists, the downstream migration of fry in the winter is well documented in other Northwest systems (Healey 1991).

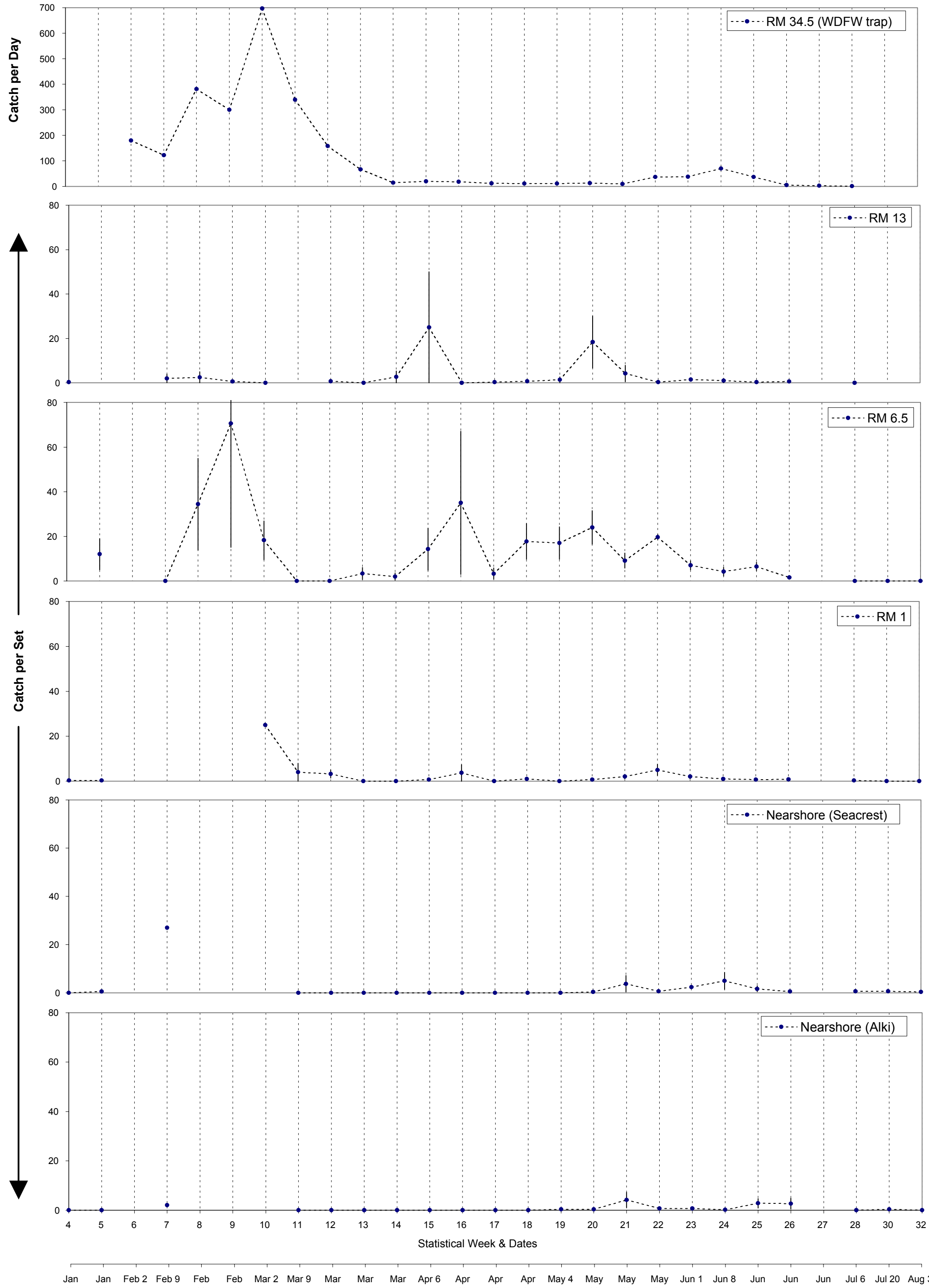

Figure 3-6. Mean catch (± 1 SE) of subyearling natural Chinook salmon by index sites and statistical week, 2003. All values are catch per river beach seine set except at RM 34.5 (screw trap).

The peak migration during late winter and early spring at RM 34.5 and RM 6.5 was not apparent in the Lower Green River (RM 13), perhaps because most fish were simply moving downstream rather than holding and rearing near the sampling site. Migrating fish caught at RM 13 may also have been less susceptible to beach seining compared with fish entrained in the screw trap at

RM 34.5, which fished continuously. During January and February, approximately three percent of the fry sampled near Kellogg Island still had visible yolk, indicating relatively recent emergence from upriver spawning gravels and rapid downstream migration. Healey (1991) notes that fry migrants from other systems have been reported with visible yolk sacs so this is not a unique occurrence.

Catches of natural subyearling Chinook salmon during spring and early summer (April 6 through June 22) were consistently higher in the transition zone at RM 6.5, averaging 14.3 fish per set, than those in the lower river at RM 13, where an average of 4.8 fish per set were caught, in the estuary at RM 1, where an average of 1.5 fish per set were caught, and in the nearshore marine index sites, where an average of only 1.0 fish per set was caught (Figure 3-6). Throughout the majority of the study period, catch rates were highest in the transition zone, averaging 64 percent of the total index catch of natural Chinook salmon caught in the lower river and estuary (Figure 3-7). Chinook salmon catches in the Lower Green River at RM 13 and near Kellogg Island represented only 20 percent and 16 percent of the catch, respectively. Catch rates in the nearshore marine shoreline areas, which were not included in the above calculations, were lower than those in all other index sites.

We examined catch rates of natural Chinook salmon at RM 6.5 compared with catches at the RM 1 and RM 13 index sites to determine whether the percentage of the total Chinook salmon catch at RM 6.5 was reduced during periods of high overall salmon abundance (all species combined). High salmon abundances were detected at RM 6.5 from approximately May 11 through June 7, in response to the presence of numerous outmigrating chum fry, and the release of hatchery Chinook salmon (Figure 3-8) during this time period. In contrast, between April 20 and May 10, catches of natural Chinook salmon at RM 6.5 represented 92 percent of the total catch at all index sites (Figure 3-7). During the period of high salmon abundance (May 11-June 7; statistical weeks 20-23), catches of natural Chinook salmon at RM 6.5 declined to 65 percent. Although catch rates of subyearling Chinook salmon at RM 6.5 remained relatively high during this period, they declined relative to catches at other index sites. After the period of high abundance catches of natural Chinook salmon at RM 6.5 increased to 77 percent, on average. The decline in the percentage of natural Chinook salmon at RM 6.5 between early May and early June might have reflected limitations in habitat capacity within the estuary transition zone, leading to dispersal of natural Chinook salmon to other areas.

Weekly catch rates of natural Chinook salmon at RM 34.5 and RM 6.5 were not highly correlated with peak flow events. For example, at RM 34.5, moderately high catches occurred during week 9 (February 23 to March 1). Although a high flow event (4,300 cfs) occurred on February 22, it was not accompanied or closely followed by a peak catch. Instead, the peak catch did not occur until the following week (Week 10, which began on March 2) when flows were relatively low and stable (1,000 cfs) (Figure 3-5). The highest flow event of the season (8,200 cfs) occurred on February 1, but catch rates at RM 34.5 then and shortly thereafter were only approximately 25 percent of those during early March, when flow was much lower. Another peak flow event (6,100 cfs) occurred on March 13 in Week 11, and catch rates during that week were high. Thereafter, daily flows were relative stable and catches at RM 34.5 did not appear to be related to flow. In contrast, peak catches at RM 6.5 occurred during Week 9, corresponding to a peak flow event, but catches during mid-March were exceptionally low and did not correspond with the high flow event or the moderately high catches at RM 34.5 during Week 11.

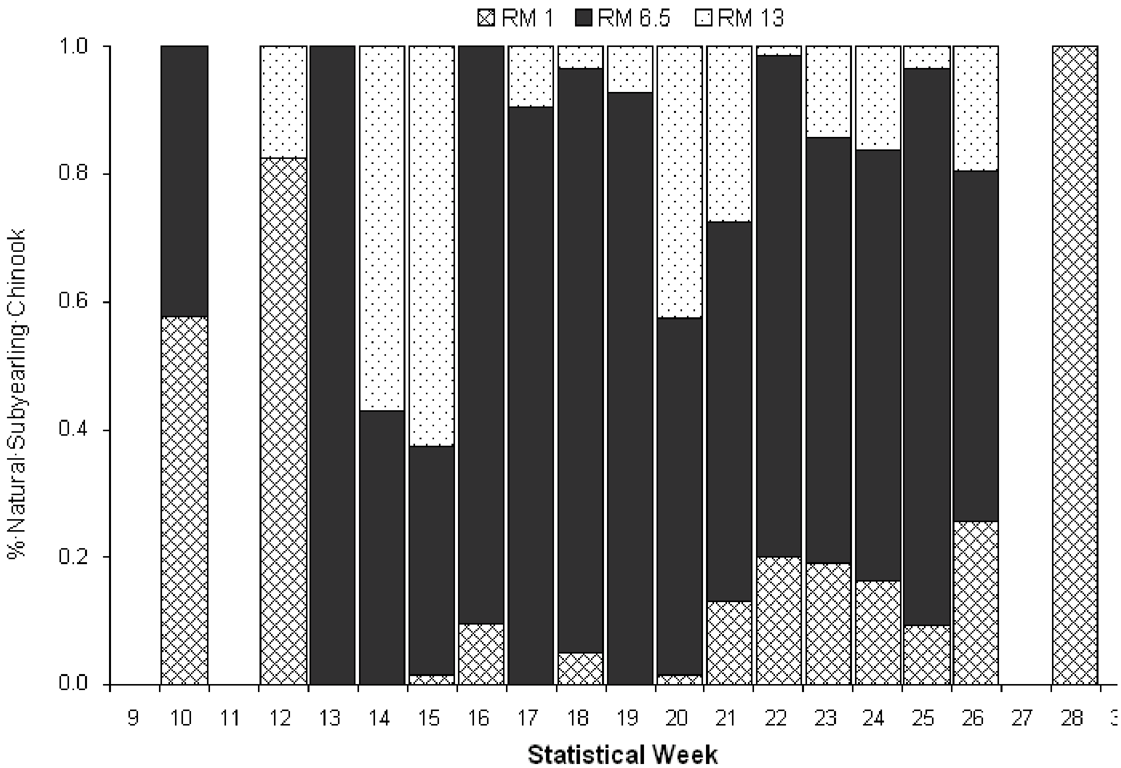

Figure 3-7. Percentage of natural subyearling Chinook salmon (vertical axis) in each of the three (RM 1, RM 6.5, and RM 13) river/estuary index sites, 2003. Only river seine catches used in these figures.

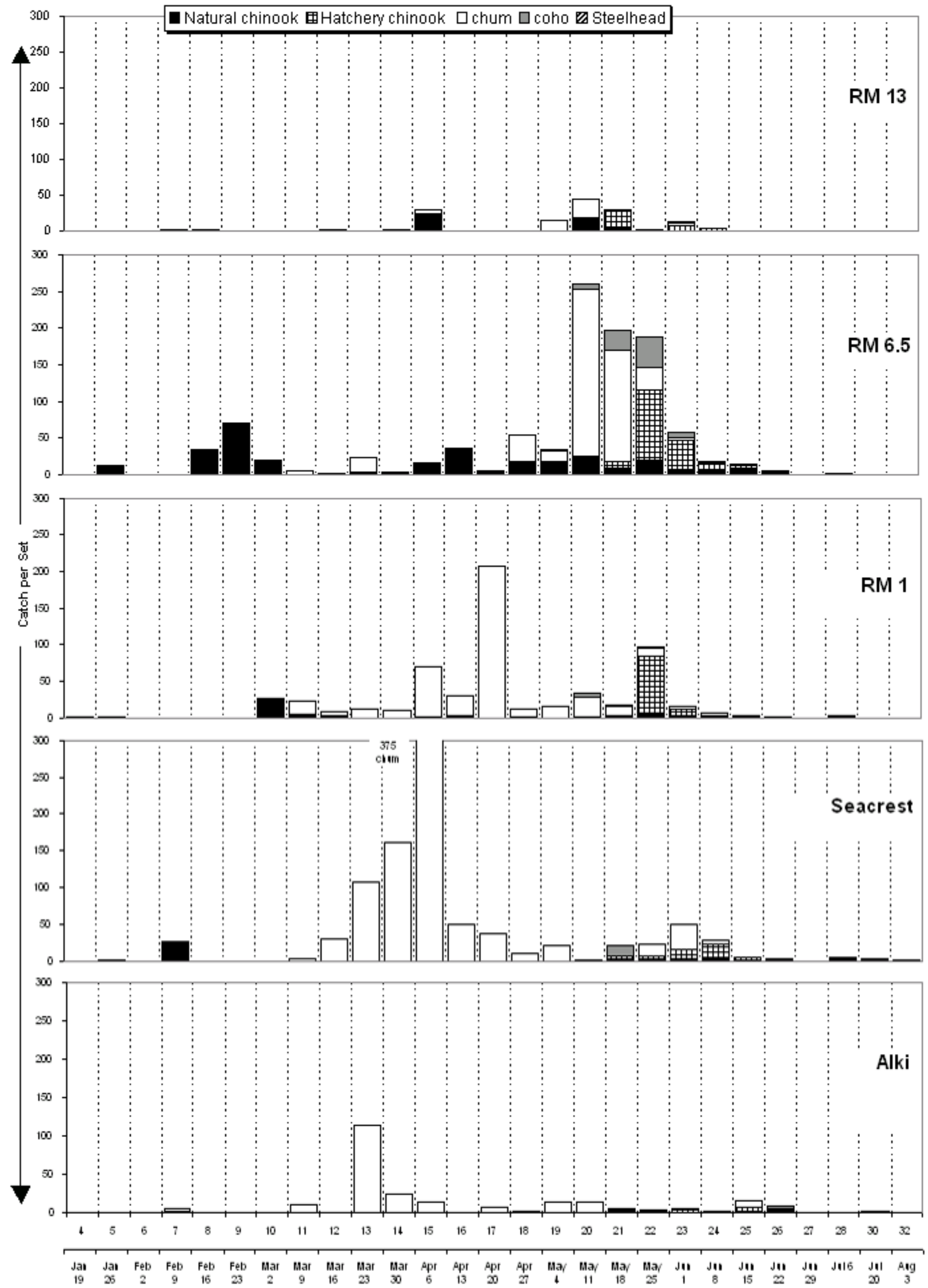

Figure 3-8. Mean catch per river beach seine set of juvenile salmon by index site and statistical week, 2003. Pink salmon not shown because only 20 were captured.

The timing of catches at RM 34.5 probably reflects both emergence timing of Chinook fry and river flow. High catch rates during a low flow period in early March suggests that some fry may be actively migrating and expressing an emergent fry life history trajectory as described in the Introduction. Late winter catch rates at RM 6.5 also seem to reflect emergence timing of fry and river flow, but the paucity of fry at RM 0-7 between mid-March and early April suggests that many fry observed at RM 6.5 during February and early March may have moved out of the watershed. Some fry from the early peak migration at RM 34.5 began to move into RM 6.5 by mid-April apparently after some rearing in the lower river.

Decreased trap efficiency during high flow events may bias the catch rate results. The actual extent of bias is not known because trap efficiency data are presently not available from WDFW. For example, information from Soos Creek (Figure 3-9) showing a peak Chinook salmon catch on February 22 was not matched by a similar mainstem peak catch and could be due to the RM 34.5 trap being inoperable during that time period.

3.3.2 Hatchery Subyearling Chinook Salmon

Approximately 3.0 million hatchery subyearling Chinook salmon were released from the Soos Creek Hatchery between May 22 and May 29, 2003 (Table 3-3). Soos Creek enters the Green River at RM 33.6, a short distance downstream from the WDFW screw trap. An additional 0.4 million subyearling Chinook salmon were released by the MIT upstream of Howard Hanson Dam (Table 3-4), but these fish have limited access to the lower river and likely contributed little to catches in and downstream from the Middle Green River during 2003. For example, in 2000, Seiler et al. (2002) estimated that 3.69 percent (10,686 fish) of the total number of subyearling hatchery Chinook salmon released above Howard Hanson Dam migrated past RM 34.5 during between March and mid-June of 2000.

At RM 13, peak catches of hatchery fish occurred during the week of May 18, the same week they were released, whereas peak catches at RM 6.5 and RM 2 occurred during the following week on May 25 (Figure 3-10). Peak Chinook salmon catches, including CWT fish, in the Seacrest nearshore area of Elliott Bay occurred between June 1 and June 8, suggesting that most hatchery fish moved through the lower river and estuary in approximately one to two weeks. This two week time period is consistent with the findings of other prior Duwamish River studies (Weitkamp 1980, 1982; Warner and Fritz 1995). However, some hatchery fish persisted in the lower river and estuary through June 28, indicating that these resided in these areas for approximately one month before swimming into Puget Sound. The largest catches of hatchery Chinook salmon occurred in the transition zone at RM 6.5, and the smallest catches occurred at Alki in Elliott Bay.

The large release of hatchery Chinook salmon is reflected in a sharp decline in the percentage of natural subyearling Chinook salmon among total Chinook salmon. During the peak migration of hatchery Chinook salmon, the percentage of natural Chinook salmon in the catches declined to approximately 20 percent at RM 13 and RM 6.5, to nine percent near Kellogg Island, and to approximately 10 to 20 percent in the Elliott Bay nearshore areas (Figure 3-11). This steep decline in the percentage of natural salmon within the total Chinook salmon catches following releases of hatchery fish reflected both a decline in the number of natural Chinook salmon outmigrating through the system, and increasing numbers of hatchery Chinook salmon in the lower river, estuary and adjacent

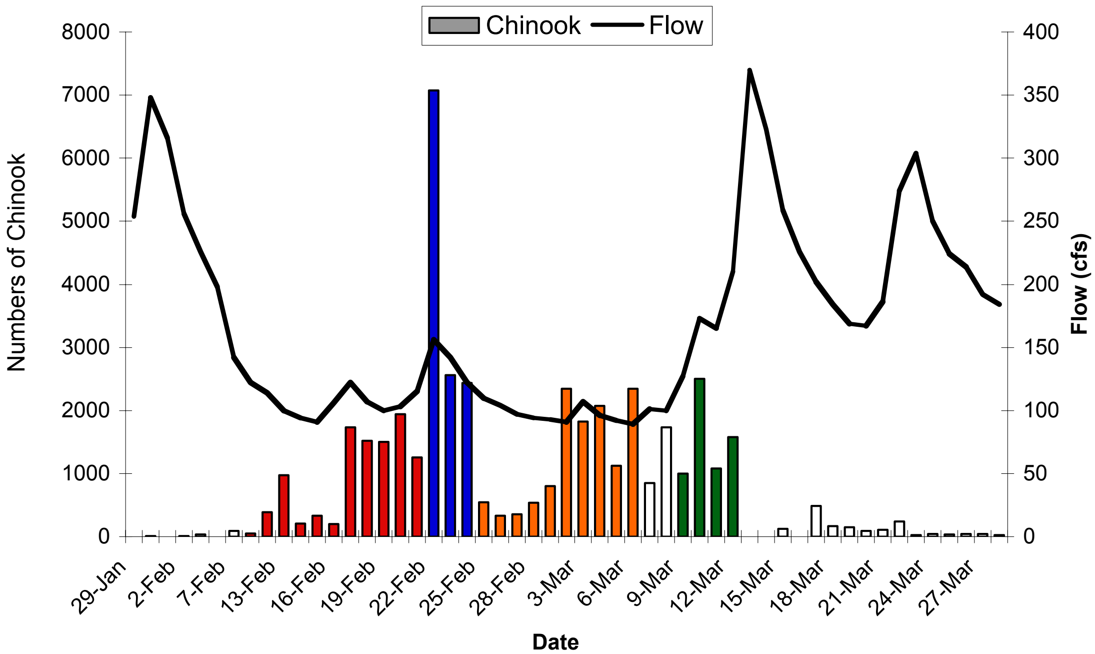

Figure 3-9. Daily comparison of flow and number of subyearling Chinook salmon spray marked at Soos Creek, 2003. Color of bar indicates color used to mark chinook, clear bar indicates Chinook salmon released unmarked.

nearshore areas. However, it should be noted that the actual numbers of natural Chinook salmon in the catches during this time period may have been somewhat less than the estimates because approximately 1.3 percent (~37,000 fish) of the three million hatchery Chinook salmon were not marked by an adipose fin clip or CWT tag, and would have been incorrectly identified as naturally-produced Chinook. The percentage of unmarked fish that had actually originated from the hatchery is unknown because total number of natural Chinook salmon is unknown[1].

[1] Given the lower abundance of natural Chinook salmon during late May and June, it is possible that unmarked, untagged hatchery salmon represented 10-20 percent of the natural catch.

Table 3-3. Salmon and steelhead releases by the Green River Hatchery complex, 2003. Source: M. Wilson, Hatchery Manager, pers. comm.

Species	Age	Location	Release Date	Number released: Ad+CWT	CWT only	AD only	% bad clip	wt (g)
Chinook	subyearling	Soos Cr	22-May	154,400	150,900	1,363,500		5.7
			23-May	4,570	48,900	316,500		6.4
			27-May	0	0	23,000		4.4
			29-May	0	0	934,000	1.33%	5.3
			Totals	158,970	199,800	2,637,000	37,186	
					Grand total:	2,995,770		
Chinook	yearling	Icy Cr	1-May	0	0	324,000	1.26%	45.4
							4,082	
Coho	yearling	Soos Cr	20-Apr	59,400	42,100	255,400	1.61%	26.7
							4,112	
Winter Steelhead	yearling	Soos Cr	1-May	0	0	37,100	0.93%	82.5
		Palmer	1-May	0	0	110,500	0.93%	82.5
		Icy Cr	1-May	0	0	7,750	0.93%	82.5
		Flaming Geyser	26-Apr	0	0	13,900	0.93%	79.6
			Totals	0	0	169,250	1,574	
Summer Steelhead	yearling	Soos Cr	1-May	0	0	31,500	1.01%	82.5
		Palmer	1-May	0	0	25,900	1.01%	82.5
		Icy Cr	1-May	0	0	2,450	1.01%	82.5
						59,850	604	

Table 3-4. Salmon and steelhead releases into the Green River watershed by the Muckleshoot Indian Tribe, 2003. Source: Dennis Moore, MIT Hatchery Manager, pers. comm.

Species	Age	Date	Location	Number released: Ad+CWT	CWT only	AD only	No mark	% bad clip	Wt (g)	Comment
Chinook	subyearling	March 20-25	Above H. Hanson Dam			402,000		~5%	2.5	No CWT, no yearlings released; clip retention not quantified, but may be similar to Soos Cr (Moore, pers. comm.)
Coho	subyearling	April 14-15	Above HH				548,000	NA	1.0	
Coho	yearling	April 30-May 7	Crisp Cr				240,000	NA	29.5	
		April 30-May 7	Crisp Cr	11,000				?	29.5	96.6% CWT retention on both groups
		April 30-May 7	Crisp Cr		39,000				29.5	
Coho	yearling	~June 1	Myrtle Edwards Net Pens				352,000			Goal is 400,000 total
			Myrtle Edwards Net Pens	50,000	(included in 50K)			?		Paul Dorn, Suquamish Tribe
			Totals:	61,000	39,000		1,140,000			
						Grand total:	1,240,000			
Steelhead	yearling	April 30-May 7	Keta Cr			34,000 Ad/left ventral (pelvic)		?	82.5	Green R Native spawn in hatchery
Chum	subyearling	March 7-April 7	Keta Cr				1,200,000	NA	1.0	No marks

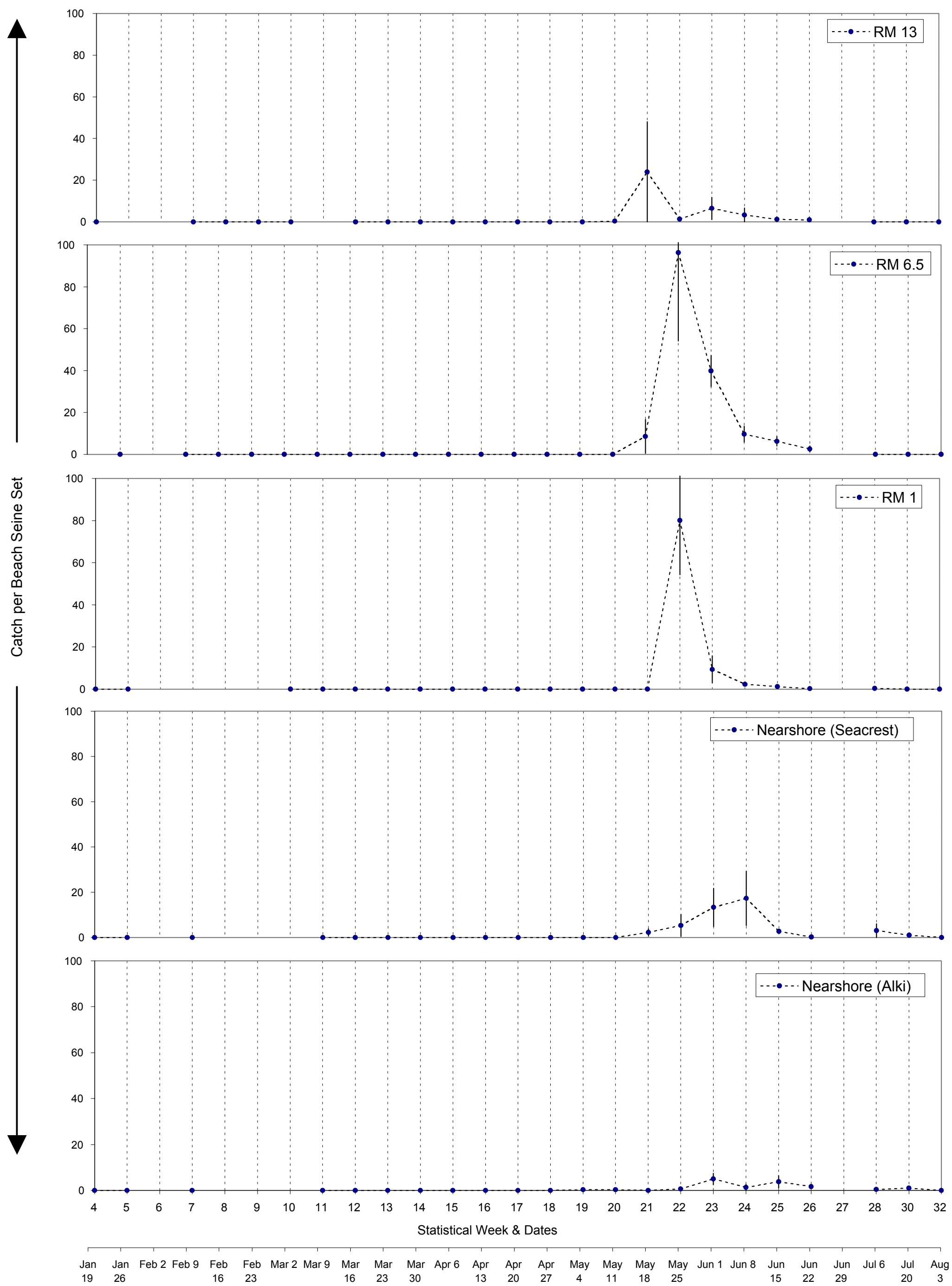

Figure 3-10. Mean catch (± 1 SE) of subyearling hatchery Chinook salmon by index sites and statistical week, 2003. All values are catch per river beach seine set. All values are catch per river beach seine set.

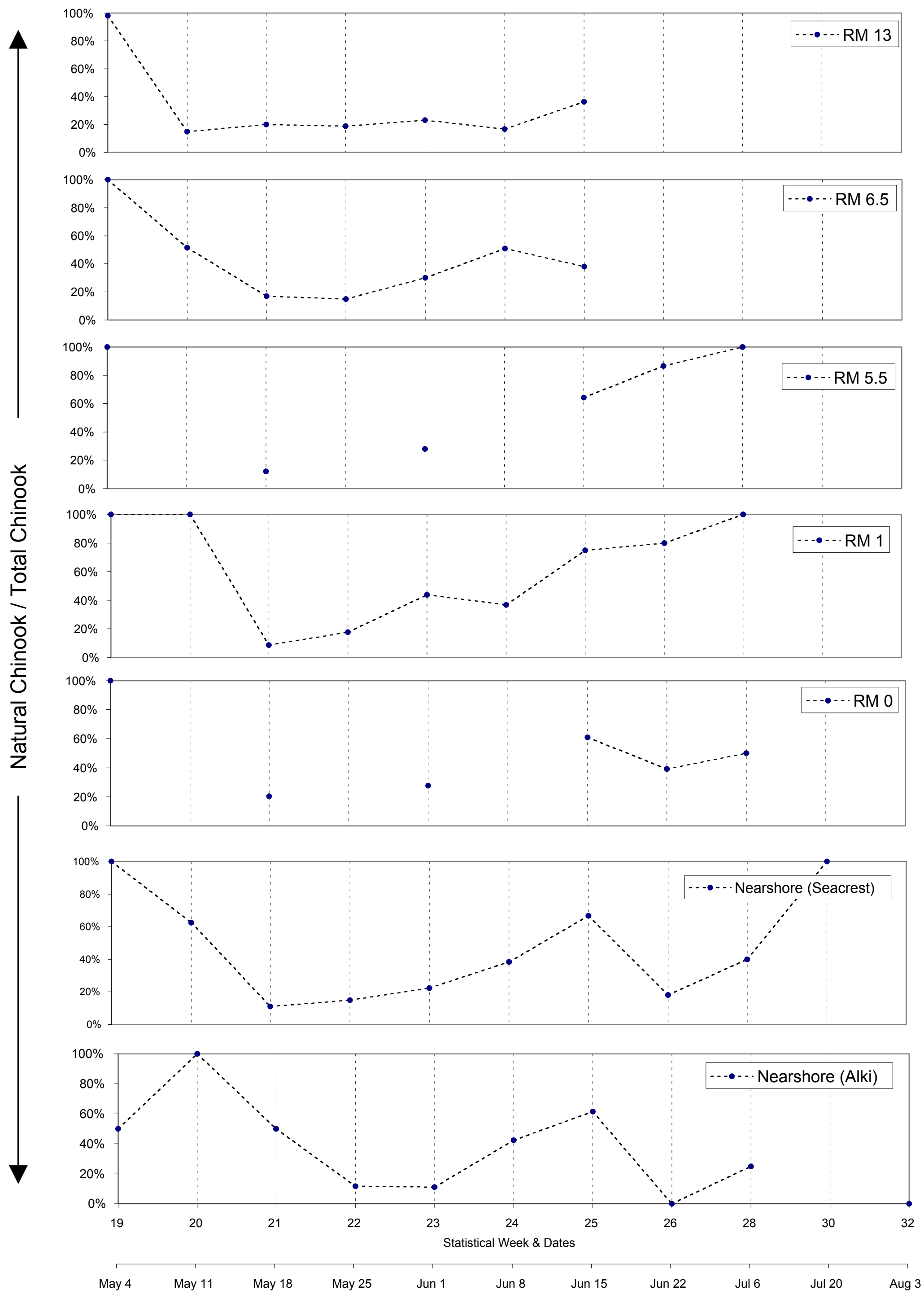

Figure 3-11. Percentage of natural Chinook salmon among subyearling Chinook salmon by location and week, May 3 to Aug 3, 2003.

A total of 17 hatchery adipose fin clipped 1+ Chinook salmon were captured between February 16 and April 6, nearly all between RM 6.5 and RM 0; none were caught at the nearshore monitoring sites. The large size of these fish, which averaged 180 mm, indicated they were either one– or two-year old hatchery fish that held over in fresh water areas from the previous year. These fish probably came from releases upstream of Howard Hanson Dam, the Soos Creek Hatchery, the Icy Creek rearing ponds or migrating into the Duwamish River from another watershed

Approximately 324,000 hatchery yearling Chinook salmon were released from the Icy Creek ponds at RM 48.3 on May 1, 2003. Twenty-three yearling hatchery Chinook salmon (adipose fin clipped)) were captured from May 4 to June 1, 2003; 52 percent were captured in at the Elliott Bay monitoring sites. These fish averaged 110 mm and were similar in size to the Icy Creek fish. The low catch rate of these yearling fish indicated that while most moved quickly through the lower river and estuary, at least a few of these fish remained in the system for a month or so after release.

3.3.4 Other Salmonids

Coho, chum, and pink salmon, and steelhead and cutthroat trout were also enumerated at the index sites. Natural subyearling Chinook, which were captured between February 16 and March 9, were moved downstream in large numbers earliest during the salmonid outmigration season (Figure 3-8). During the study period, natural Chinook salmon represented 17 percent of the total catch of salmonids in the river and estuary compared with 18 percent for hatchery Chinook salmon. In addition, 59 percent of the total number of outmigrating salmonids were chum fry, 2.1 percent were natural coho, 3.9 percent were hatchery coho, 0.2 percent were steelhead, and less than 0.1 percent were pink fry and cutthroat trout (Table 3-5). The similar percentages of natural and hatchery subyearling Chinook salmon reflected the longer time period over which natural fish were captured in the river, and their longer freshwater residence time, rather than equal abundances of the two stocks.

The highest chum catches occurred between March 16 and May 24. While most of the chum were captured in Elliott Bay at Seacrest, substantial numbers of chum were also captured at RM 6.5 and RM 1. Nearly 90 percent of the coho salmon (yearlings) were captured at RM 6.5. Between river and estuarine sampling, 56 percent of the total number of salmonids caught in the river and estuary were captured in the transition zone at RM 6.5, followed by 34 percent captured near Kellogg Island, and 9 captured percent in the Lower Green River at RM 13. Except for chum fry, catches of salmonids in the nearshore marine areas were consistently low (Figure 3-8), reflecting rapid dispersal within Elliott Bay and other marine areas.

3.3.5 Supplemental Beach Seine Sampling

Most of the supplemental beach seine sets were conducted at the Turning Basin (RM 5.5), RM 4, and RM 0, but several sets were also made at RM 1 and at the Elliott Bay sites. These supplemental sets were typically made with the Puget Sound Protocol seine (PSP), which is larger than the river seine used to sample the index sites. Comparison of river seine and the PSP seine catches made at the same location and week indicated that the PSP net captured twice as many fish, including subyearling Chinook salmon salmon, on average, as the river seine (two factor ANOVA: week and gear type; df = 1, 10, 277; $F = 5.33$; $P = 0.022$). Thus, PSP catches of Chinook salmon were multiplied by 0.5 in order to make them comparable to the river seine catches (see Appendix E for statistics details).

The combined supplemental and index catch data show that relatively high catches of natural and hatchery subyearling Chinook salmon occurred at RM 5.5 and RM 6.5 (Figures 3-12 and 3-13). Catches at RM 0 (primarily near Terminal 5) and at the Elliott Bay nearshore sites were typically lower than those at upstream sites. As mentioned above, the highest Chinook salmon catches occurred primarily in the low velocity and shallow depths of the transition zone (RM 5.5-RM 6.5).

Table 3-5. Average catch of salmon and steelhead per seine set and the percentage of the catch by index site, March 2 to July 6, 2003. The number of sets conducted at each site is shown; additional sets made but not included if weekly sets not made at all three index sites.

Species	RM 13	RM 6.5	RM 2	Total
Natural chinook	3.3	10.8	2.7	5.6
	20%	64%	16%	17%
Hatchery chinook	2.2	9.6	5.5	5.8
	13%	55%	32%	18%
Coho	0.2	5.0	0.4	1.9
	3%	90%	7%	6%
Chum	3.2	29.1	24.7	19.0
	6%	51%	43%	59%
Steelhead	0.15	0.03	0.04	0.1
	68%	14%	18%	0.2%
Totals	9.1	54.6	33.3	32.3
	9%	56%	34%	
No. of sets	60	82	62	204

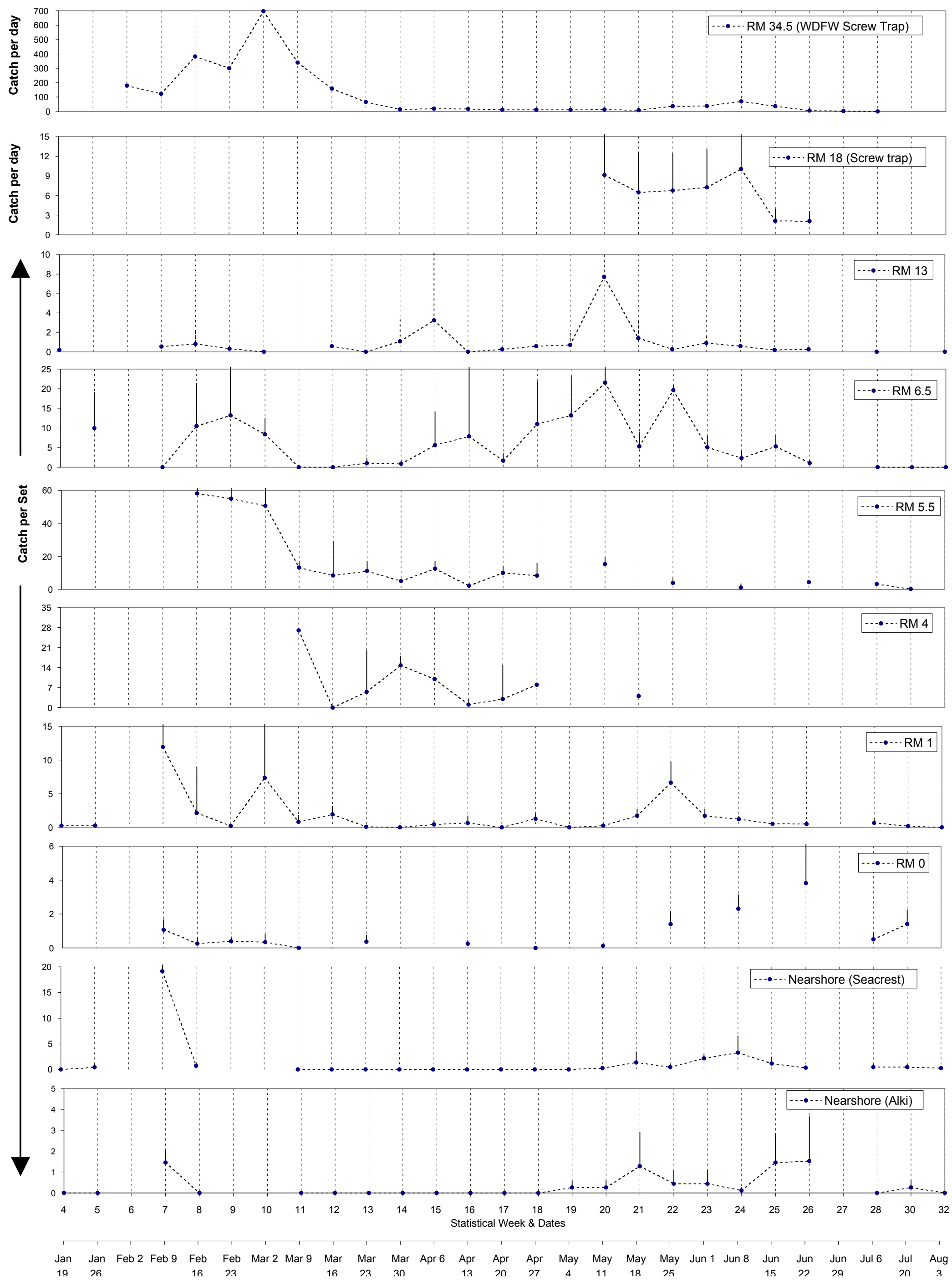

Figure 3-12. Geometric mean catch (+ 1 SE) per beach seine set of subyearling hatchery Chinook salmon by location and statistical week, 2003. Fish were sampled by screw trap at RM 18 (catch per day). Note change in Y-axis scale. Hatchery fish released from Soos Creek on May 22-29, 2003; tribal fish released above dam in March.

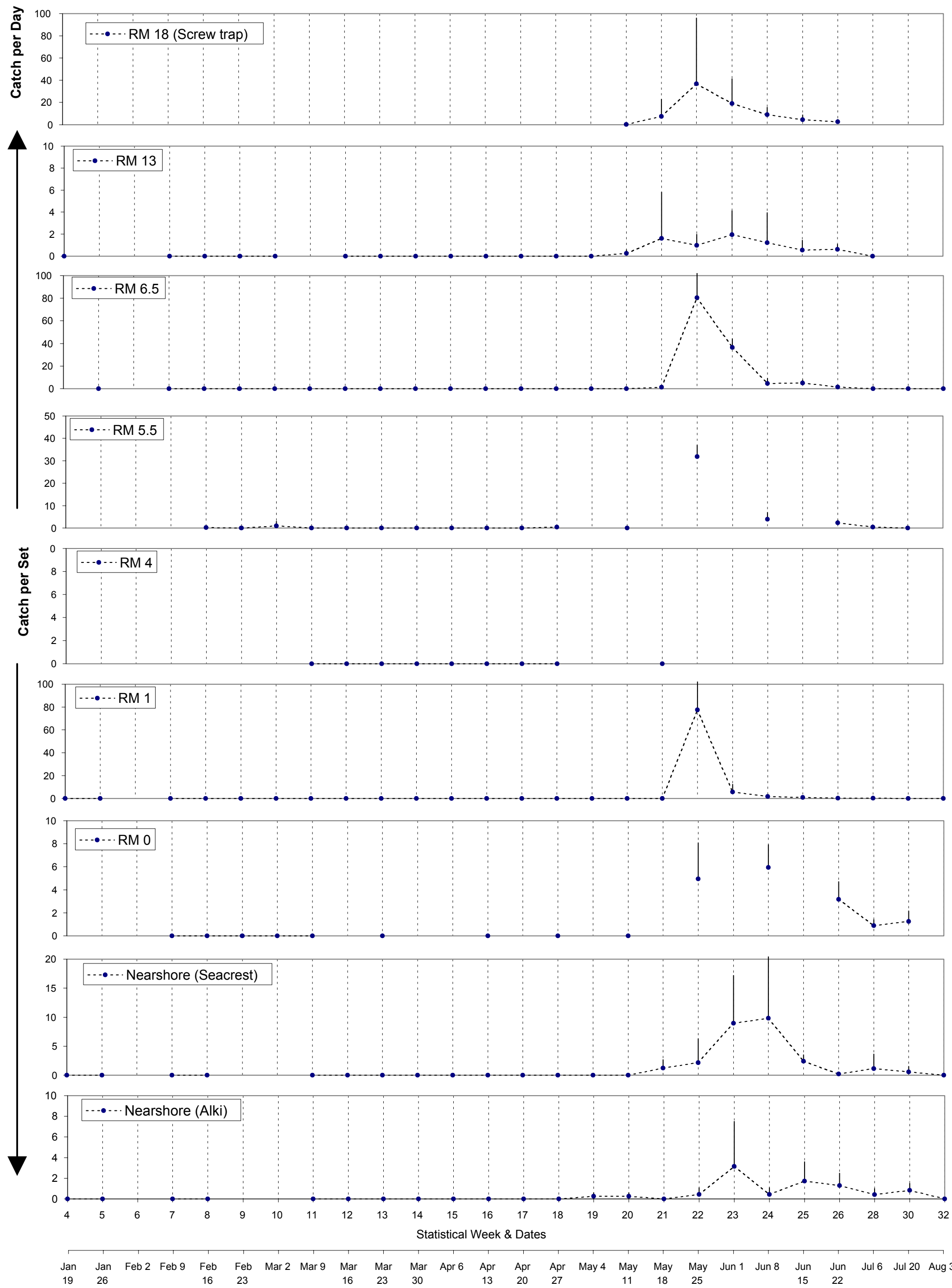

Figure 3-13. Geometric mean catch (+ 1 SE) per beach seine set of subyearling hatchery Chinook salmon by location and statistical week, 2003.
Fish were sampled by screw trap at RM 18 (catch per day). Note change in Y-axis scale. Hatchery fish released from Soos Creek on May 22-29, 2003; tribal fish released above dam in March.

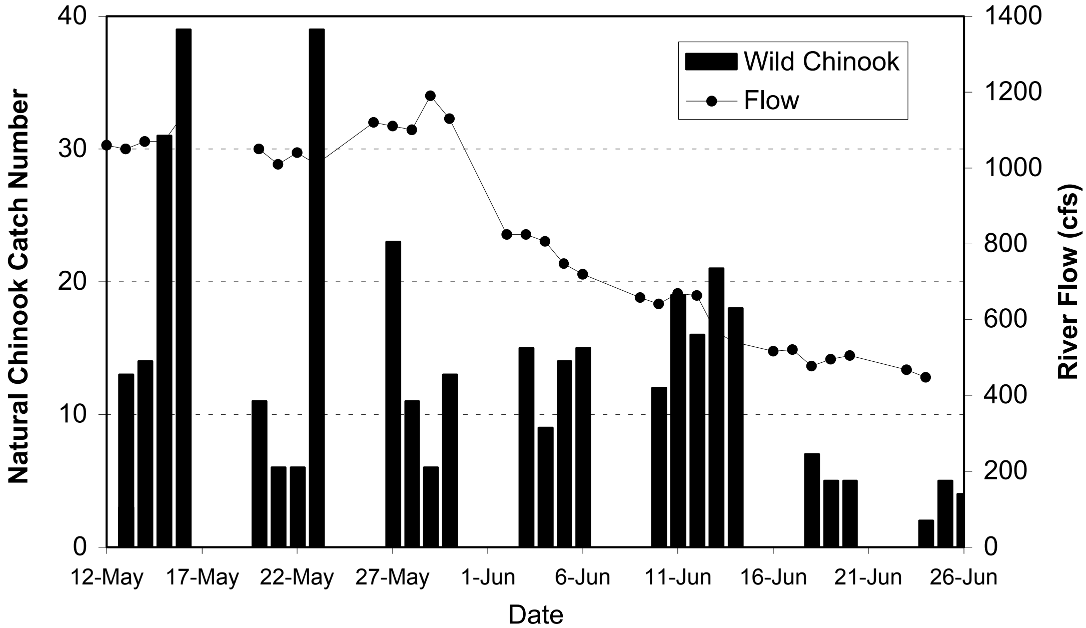

Figure 3-14. Catch per day of natural subyearling Chinook salmon in relation to river flow at the RM 18 screw trap, May 12-June 26, 2003.

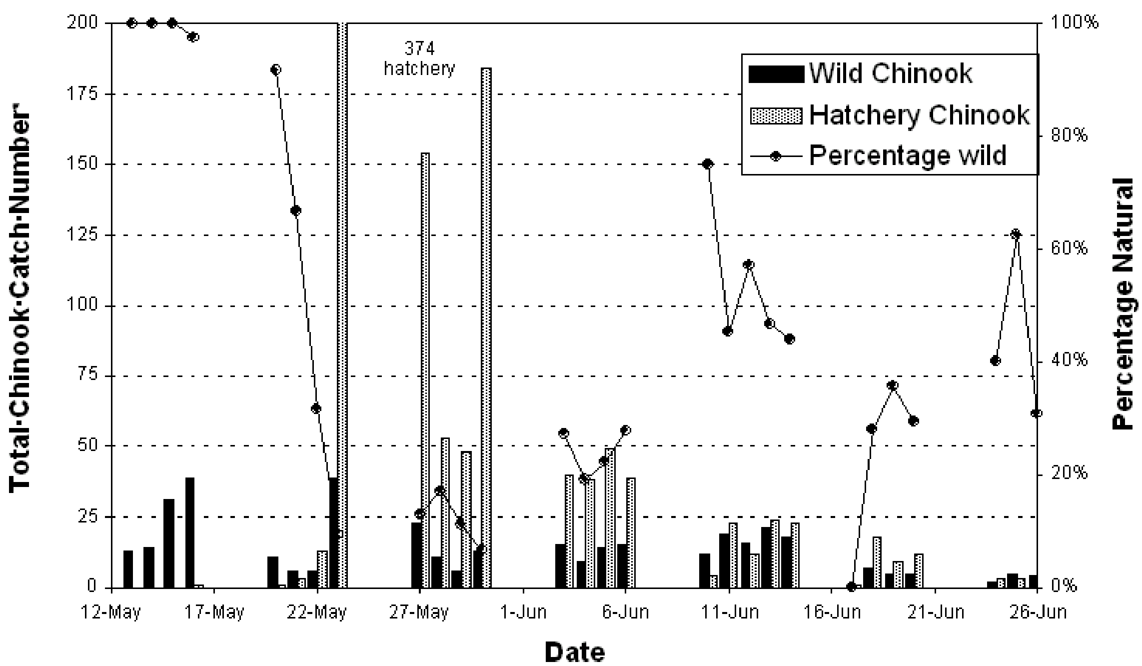

Figure 3-15. Catch per day of natural and hatchery subyearling Chinook salmon at the RM 18 screw trap, May 12-June 26, 2003.

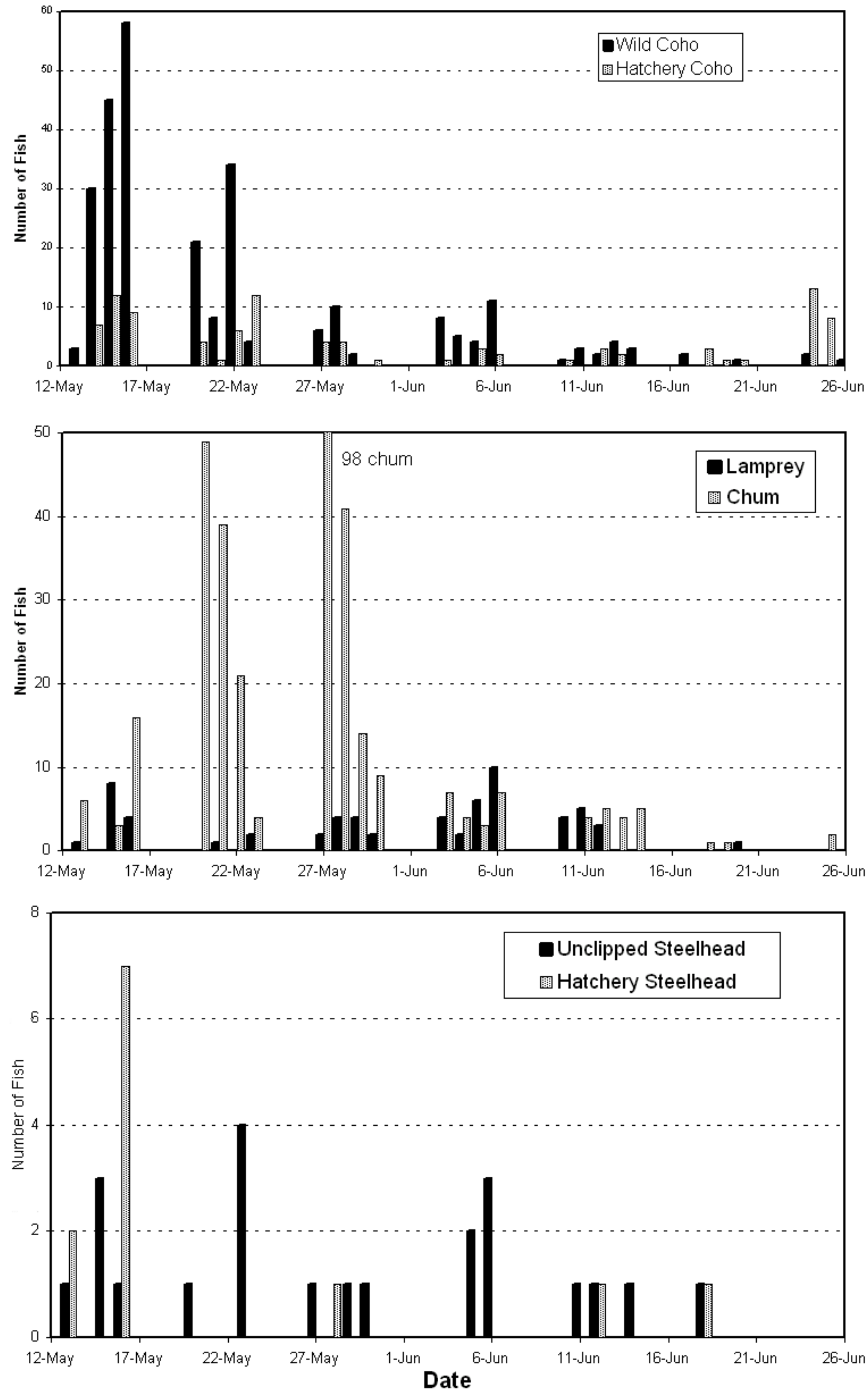

Figure 3-16. Times series of daily fish catches at the RM 18 screw trap, 2003.

3.3.6 RM 18 Trap

Catch rates of juvenile Chinook salmon at the screw trap at RM 18 in Kent were examined for hatchery versus natural stock composition, and for potential effects of flow on the migration of fingerling Chinook salmon. The trap was operated from May 13 to June 26. Daily catch rates of natural subyearling Chinook salmon were variable, but catch per week remained relatively stable until declining in mid-June (Figure 8). Catch rates were not correlated with river flow, which averaged 1,050 cfs between mid-May and late May, thereafter declining to 450 cfs by late June. At these flows velocity was not likely great enough to sweep small fry through the study area.

The percentage of natural Chinook salmon declined sharply following the initial release of hatchery Chinook salmon on May 22, 2003. Natural Chinook salmon represented approximately 10 percent of the total Chinook salmon catch during late May, increasing to 20 percent in early June, and between 30 and 65 percent from mid- to late June (Figure 3-15). Catches of hatchery Chinook salmon were high in late May (up to 374 fish per day), then declined steadily to approximately three per day in late June, indicating that most hatchery Chinook salmon had quickly moved through the RM 18 monitoring site. Although some fish remained in this part of the river for at least a month after being released from the hatchery between May 22 and May 29.

Daily catches of other species at the RM 18 trap are shown in Figure 3-16. Natural yearling coho salmon were relatively abundant, approximately 30 per day, during mid-May, before declining to approximately one per day in late June. Chum fry were especially abundant in late May. Steelhead were captured in small numbers throughout the sampling period. Sub-adult river lamprey were also consistently captured in small numbers between mid-May and mid-June.

3.4 YEAR 2003 CHINOOK SALMON SIZE AND GROWTH

3.4.1 Natural Subyearling Chinook Salmon

The sizes of natural subyearling Chinook salmon were examined from late January through July 2003. Fork length data (live measurements) were collected at monitoring stations throughout the study reach, including the WDFW screw trap at RM 34.5, the Soos Creek trap, at RM 0 in the Duwamish Waterway (Terminal 5), and the Seacrest site in Elliott Bay.

Time series of mean lengths sampled at RM 34.5, RM 18, RM 13, RM 4 through RM 6.5, RM 1 through 0, and Seacrest indicated that natural subyearling Chinook salmon grew in size over time within all the study reaches (Figure 3-17 and 3-18). Fish sampled at the Soos Creek and at RM 34.5, which are near the spawning grounds, tended to be smaller on any given date than those measured downstream on the same date. The relatively low increase in size among fish sampled at all sites through mid-April (week 15) reflects the capture of relatively young fish and their slower growth rate during late winter and early spring, when water temperatures are relatively low. Fish measured in the reaches between RM 0 to 1 and RM 4 to 7 were similar in size (Figure 3-17 and 3-18), indicating that catches collected in these two subreaches could be combined for further analyses.

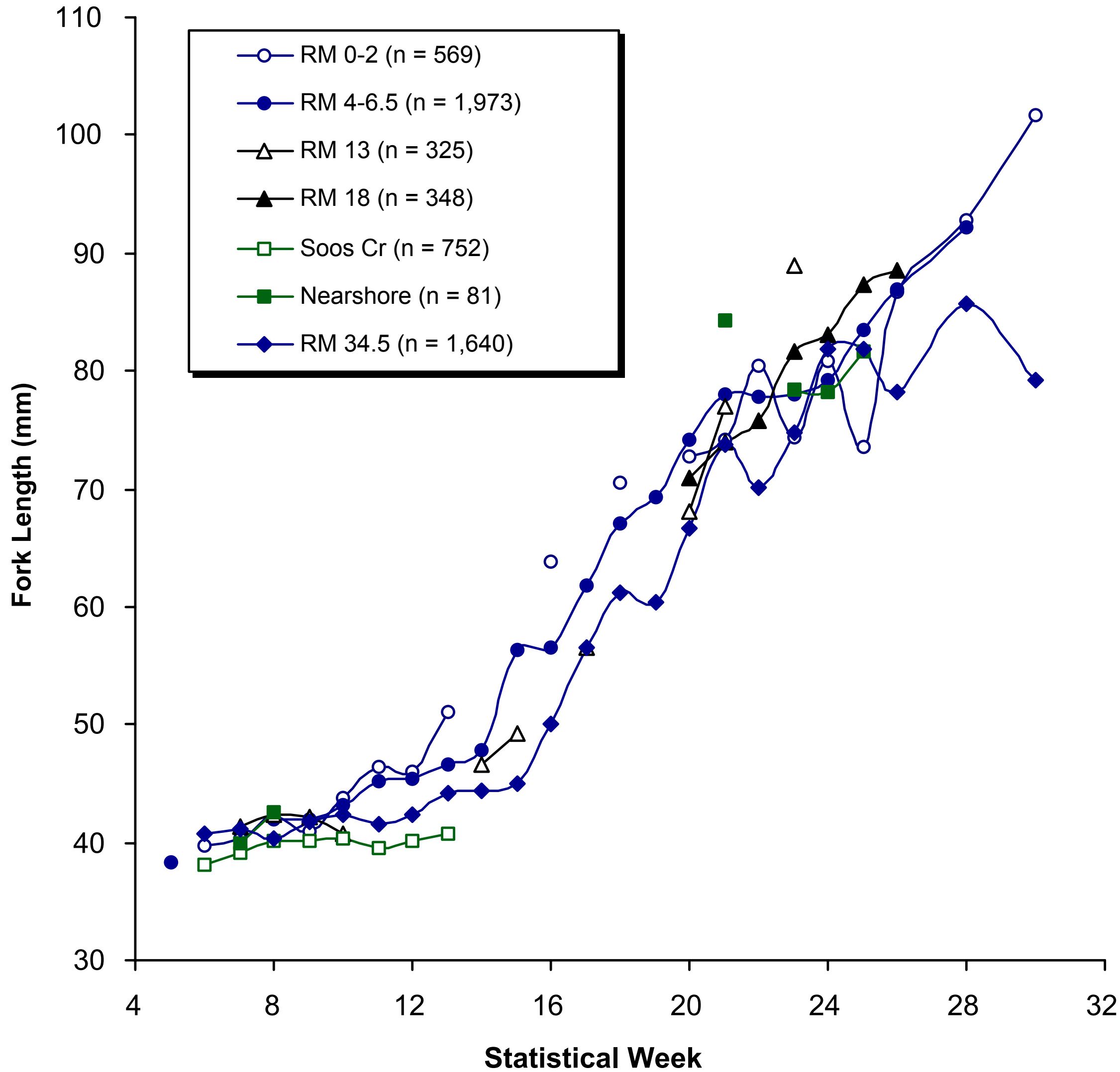

Figure 3-17. Mean length (mm) of natural subyearling Chinook salmon (vertical axis) collected from a variety of locations in the Green River watershed, February to July 2003.
Each mean length based on measurements of five or more fish. Total number of fish measured at each site is shown in the legend.

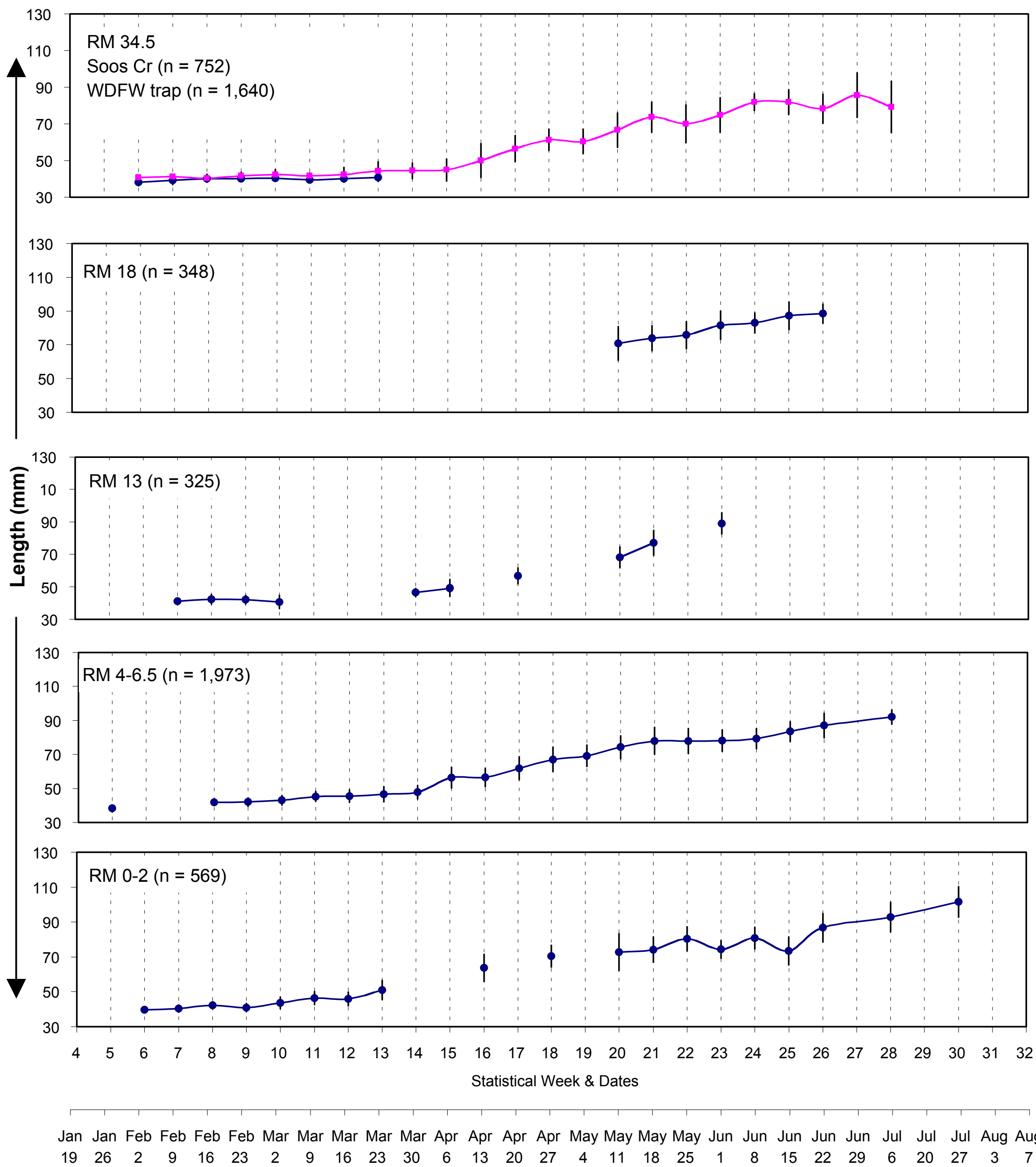

Figure 3-18. Mean length (± 1 SD) of natural subyearling Chinook salmon by location and statistical week, 2003.
Mean values based on measurements of five or more fish. Total fish measured per station shown in graph legends.

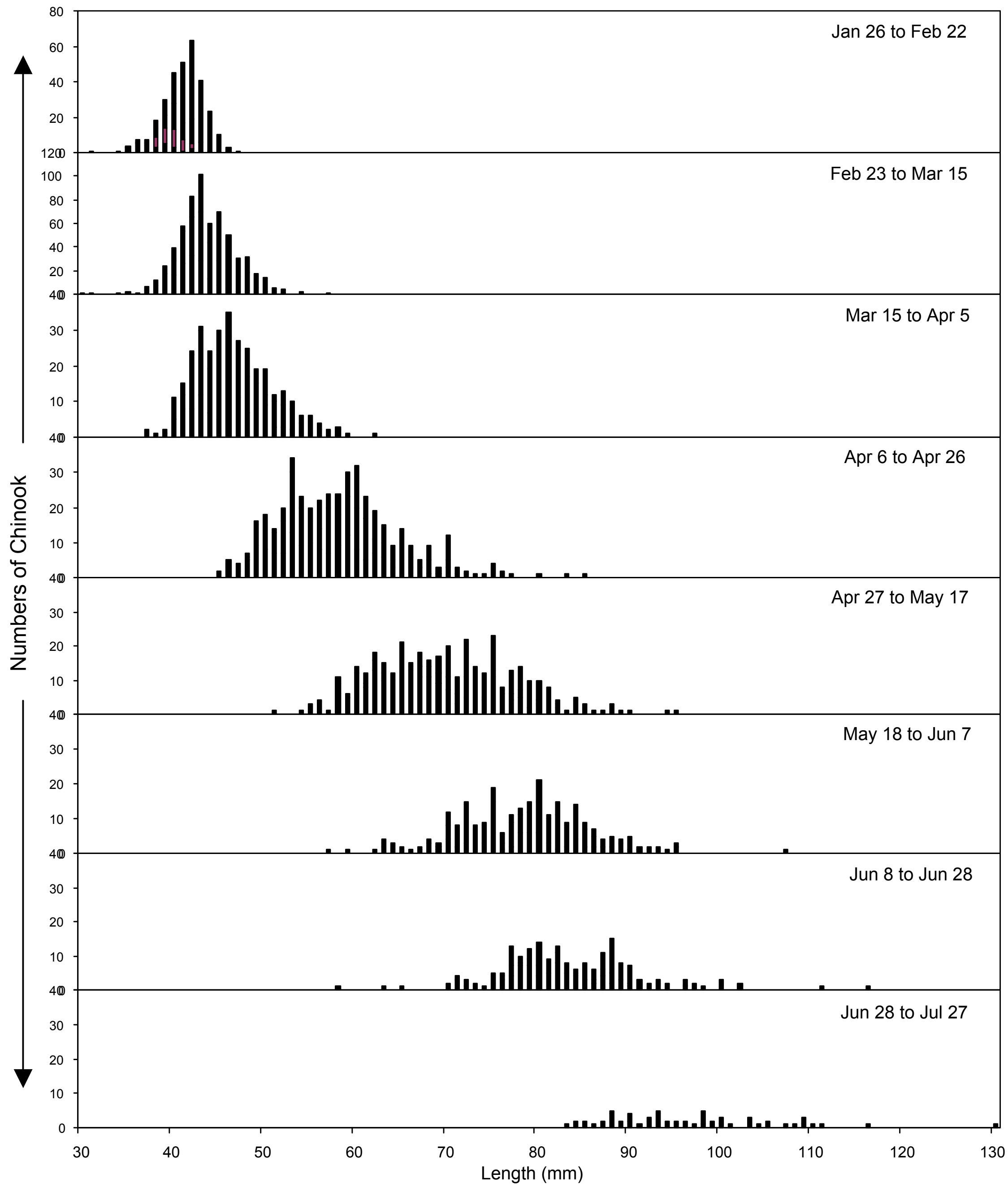

Figure 3-19. Length frequency distributions of natural subyearling Chinook salmon collected from RM 0 to 6.5 areas of the Duwamish River, late January through July 2003. Note change in Y-axis scale.

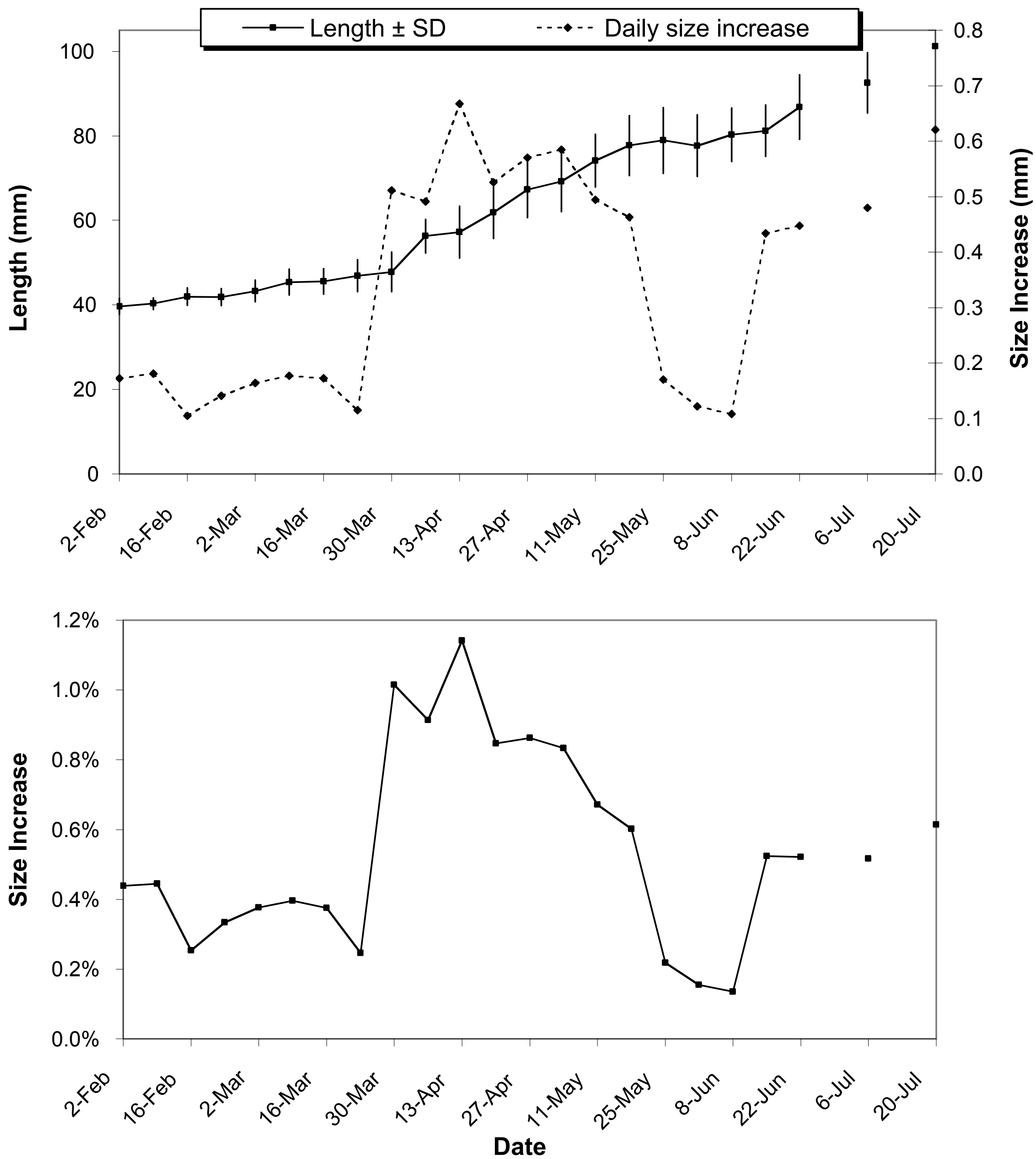

Figure 3-20. Change in mean length of natural subyearling Chinook salmon in the Duwamish River (RM 0-6.5) during February through July 2003. Upper graph shows mean length (± 1 SD) and length increase per day; lower graph shows length increase per day as a percentage of fork length.

Length histograms of subyearling Chinook salmon collected between RM 0 and 7 typically had a normal distribution throughout the sampling season (Figure 3-19), although a slight positive size skew was noticeable in the data collected between March 16 April 26, which probably reflected the recent mixing of younger fish with larger, older subyearling Chinook salmon in the estuary and transition zone during that time period. A bimodal distribution, which might reflect the presence of unmarked hatchery salmon, was not apparent prior to mid-May, but a weak bimodal pattern became apparent in June, although it was too weak to conclude that it resulted from catching sizeable numbers of unmarked hatchery salmon. The length frequency graphs show that the range in size of natural subyearling Chinook salmon increased from approximately 13 mm (34-47 mm) in February, to 22 mm (37-59 mm) in March, to 44 mm (51-95 mm) in early May, before declining to approximately 31 mm between late May and late July. This variation in fish size on a given date reflects variation in growth and time since emergence from the spawning gravels.

The mean length of subyearling natural Chinook salmon sampled in the reach between RM 0 and RM 6.5 increased from approximately 40 mm in early February, to 56 mm in early April, to 72 mm in early May, to 79 mm in early June, and to 90 mm in early July (Figure 3-20). This observed change in size reflected a combination of growth, immigration into the study area, and emigration from the study area. While noting this potential bias, we calculated an index of growth based on the change in mean size over time. Healey (1991) estimated that this approach, which has been applied in a number of estuaries, underestimated actual growth by approximately 50 percent, based on comparisons with studies using marked salmon.

The daily increase in the length of natural Chinook salmon collected in the reach between RM 0 and RM 6.5 was relatively low in February and March (approximately 0.15 mm, or 0.35 percent, per day). The growth rate of these fish increased considerably during from April through mid-May to 0.54 mm, or 0.86 percent, per day (Figure 3-20). However, from late May until mid-June, daily growth declined 76 percent to approximately 0.13 mm, 0.17 percent, per day. This decline in growth corresponded with the period of hatchery Chinook salmon releases and with relatively high abundances of hatchery Chinook salmon in the RM 0 to 7 reach (Figure 3-21). Catches of hatchery Chinook salmon reached 95 fish per set at the RM 6.5 transition area sampling site, where numerous natural Chinook salmon were also captured. Following a sharp decline in the abundance of hatchery Chinook salmon in mid-June, daily growth of natural Chinook salmon increased to 0.44 mm, 0.52 percent, per day during the last two weeks in June, corresponding to a 230 percent increase in growth rate compared with the previous three weeks when hatchery fish were present.

Growth of natural subyearling Chinook salmon upstream of RM 34.5 was examined to determine whether the sharp reduction in growth among fish sampled in the RM 0 to 7 reach might reflect immigration of natural salmon from the Middle Green River. The RM 34.5 screw trap site was upstream of Soos Creek, therefore fish collected there had interacted with relatively few subyearling hatchery Chinook salmon[2]. At RM 34.5, the daily Chinook salmon growth rate was relatively low through March (0.06 mm per day), high in April and early May (0.57 mm per day), and moderate in late May and June (0.41 mm per day) (Figure 3-22). During the period of hatchery release and reduced growth of fish in the RM 0 to 7 reach from late May to mid-June, the daily growth rate of natural Chinook salmon at RM 34.5 averaged 0.44 mm (0.58 percent), which was considerably greater than that in RM 0 to 7 (0.13 mm or 0.17 percent per day).

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[2] In 2000, Seiler et al. (2002) estimated that 10,686 subyearling hatchery chinook salmon (3.69 percent of total release by the Muckleshoot Indian Tribe) released above Howard Hanson Dam in 2000 were captured at the RM 34.5 screw trap from late march through mid-June. Additionally, some larger Chinook salmon may escape downstream during winter and spring when the dam is operated with little or no storage. No Chinook salmon were intentionally released at the Keta Creek Hatchery.

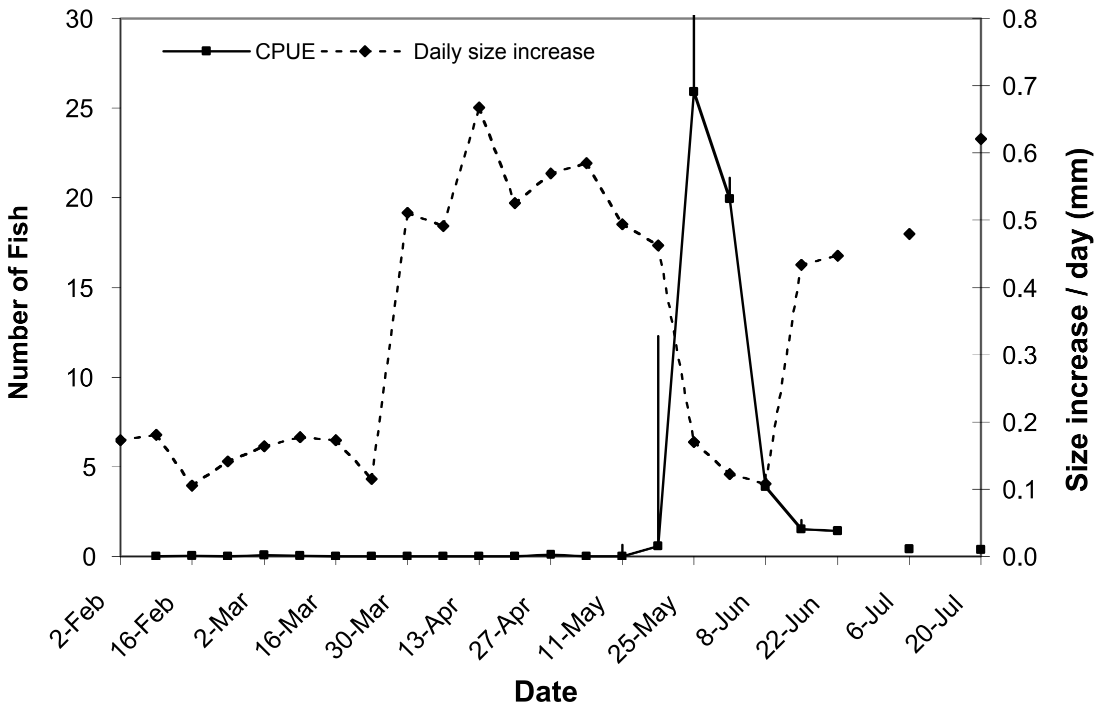


Figure 3-21. Change in daily size of natural subyearling Chinook salmon in relation to the number of hatchery Chinook salmon captured per beach seine set. CPUE are geometric means + 1 SE. All fish sampled within RM 0-6.5, 2003.

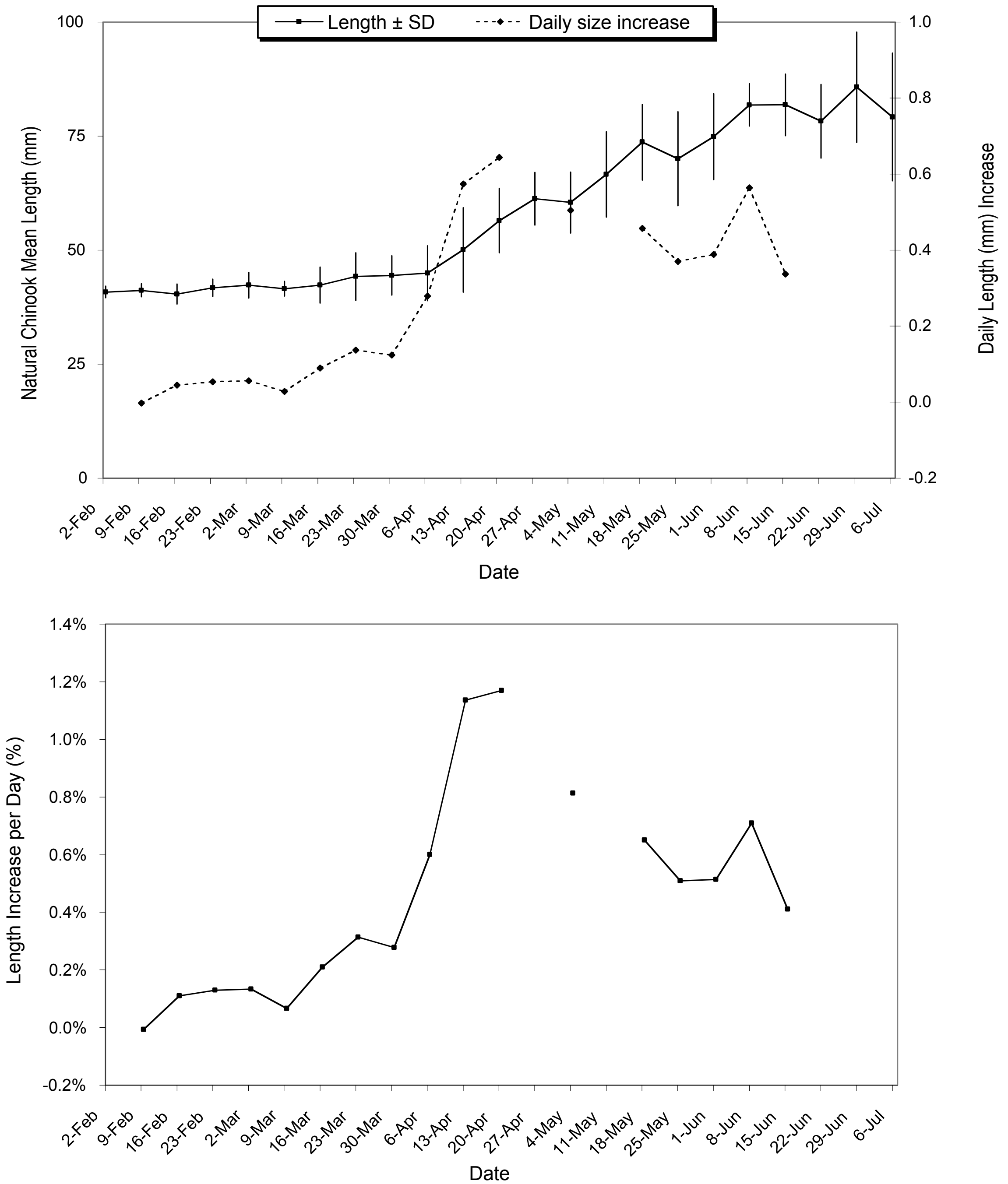


Figure 3-22. Change in mean length of natural subyearling Chinook salmon in the Middle Green River (RM 34.5; WDFW trap) during February through early July 2003. Upper graph shows mean length (± 1 SD) and length increase per day; lower graph shows length increase per day as a percentage of fork length.

Comparison of weekly Chinook salmon growth rates at RM 34.5 and in the RM 0 to 7 reach between April 13 and June 15 suggested that the growth rate of Chinook salmon in the Middle Green River exceeded that of Chinook salmon in the transition zone and estuary (paired t-test; df = 7, t = 2.164, P = 0.067). Lower growth in RM 0-7 was largely due to the low growth rate during the period of hatchery releases.

Although the decline in the Chinook salmon growth index corresponded with the release of 3.0 million hatchery Chinook, it also corresponded with an increase in natural Chinook salmon moving into the RM 0 to 7 reach from the Middle Green River (Figure 3-6). During May, the mean length of natural Chinook salmon increased with distance from the Middle Green River. For example, fish captured at RM 34.5 averaged 70.1 mm, while those captured at RM 18 and between RM 0 and 7 averaged 73.5 mm and 76.9 mm, respectively. However, from early to mid-June, the mean natural fish length at RM 18 (83.95 mm) exceeded the average lengths at both RM 34.5 (79.5 mm) and RM 0-7 (79.7 mm). Moreover, fish captured at the RM 18 trap appeared to be migrating downstream rather than rearing in that area. Thus, it does not appear that the reduction in daily growth of fish within the RM 0 to 7 reach during late May and early June was significantly influenced by the immigration of smaller fish from the Middle Green River. Furthermore, the total catch of fingerlings at RM 34.5 in June composed only about 9 percent of the total number of fry outmigrating in February and March, indicating that relatively small numbers of fish were moving downstream in June. These findings support the hypothesis that growth reduction was related to the release of hatchery Chinook salmon in 2003.

Growth rates of natural Green/Duwamish River Chinook salmon were compared with other systems (Table 3-6). Green/Duwamish River Chinook salmon generally fall well within a wide range of reported values except for the late May to early June time period when hatchery fish were present and growth rate was low.

3.4.2 Hatchery Subyearling Chinook Salmon

Subyearling hatchery Chinook salmon were present in relatively large numbers beginning in mid-May. Growth of subyearling hatchery Chinook salmon was low from late May through mid-June, averaging 0.04 mm per day (0.05 percent), then growth increased substantially from late June until late July (0.88 mm or 0.95 percent per day) (Figure 3-23). The period of low growth of hatchery Chinook salmon corresponded with the period of low growth of natural Chinook salmon and high abundance of hatchery salmon. Higher growth also occurred during the period of low salmon abundance when water temperatures were increasing. This finding supports evidence described above that large numbers of hatchery salmon may have inhibited the growth of natural Chinook salmon in the late spring.

3.4.3 Natural versus Hatchery Subyearling Chinook Salmon

During mid-May through late July, subyearling hatchery Chinook salmon were significantly longer than natural Chinook salmon (two factor ANOVA (stock, week): df = 1, 7, 1742, F = 45.590, P < 0.001). The difference in mean size was relatively small from mid-May through mid-June (2.1 mm), but hatchery fish tended to increase in size more rapidly than natural Chinook salmon during late June and July (size differential: 5 mm), when relatively few fish remained in the lower river and estuary (Figure 3-23). The difference in growth rate between hatchery and natural Chinook salmon during late June and July is indicated by the nearly significant interaction term of the two-factor analysis of variance (ANOVA; df = 1, 7, 1742, F = 1.856, P = 0.073). The faster growth of hatchery Chinook salmon observed during late June and July may have reflected: (1) high fat reserves at the time of release from the hatchery; (2) greater consumption of prey in the watershed by the relatively large hatchery Chinook; and/or (3) differential size-based migration speeds of hatchery versus natural Chinook. In other words, it is

Table 3-6. Comparison of subyearling Chinook salmon growth rates in various watersheds.
Data sources: Healey 1991, Congleton et al. 1981, this report.

Estuary	Period	Method	Growth per day (mm)
Duwamish, 2003	April-mid-May	unmarked	0.54
	Late May-early June	unmarked	0.13
	late June	unmarked	0.44
Green R (RM 34.5), 2003	April-mid-May	unmarked	0.57
	Late May-June	unmarked	0.41
Duwamish, 2002	May	unmarked	0.66
	mid-June	unmarked	0.14
	late June-July	unmarked	.29-.44
Green R (RM 34.5), 2003	Late May-early June	unmarked	0.57
	mid-June to mid-July	unmarked	0.38
Skagit	spring	bioenergetics	0.8
British Columbia			
Nintinat R	1975-77	unmarked	0.33
Nintinat R	1975-77	marked	0.62
Fraser R	mid-May thru June	unmarked	0.56
Fraser R	mid-May thru June	unmarked	0.39
Nanaimo R	April thru June	unmarked	0.5
Nanaimo R	April thru June	marked	1.32
Cowichan R		unmarked	0.22
Courtenay R		unmarked	0.61
Campbell R		unmarked	.46-.55
Columbia R	April-October	unmarked	0.44
Oregon			
Sixes R	April-early June	unmarked	0.9
Sixes R	June thru August	unmarked	0.07
Sixes R	September-November	unmarked	0.5
California			
Sacramento R	March-July	unmarked	0.48
Sacramento R/San Joaquin R		marked	0.86
Sacramento R/San Joaquin R		marked	0.53

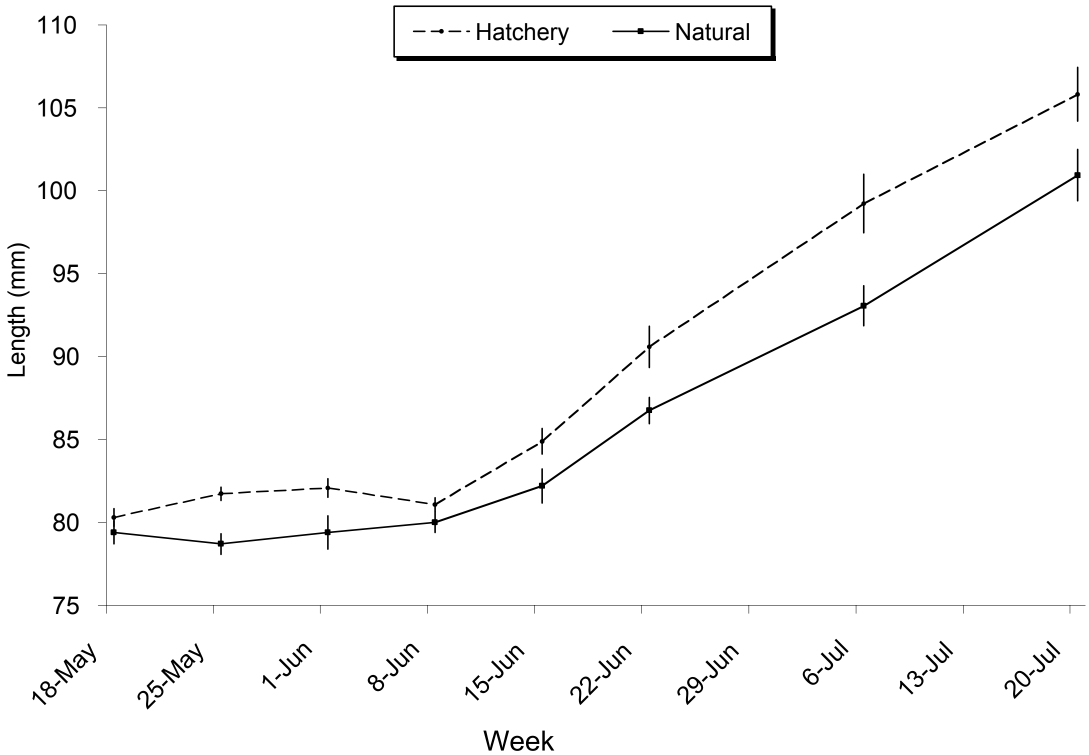


Figure 3-23. Comparison of mean length (± 1 SE) of natural and hatchery Chinook salmon (vertical axis) collected in the Duwamish River (RM 0-18) and nearshore areas, May through July 2003.

possible that a greater percentage of smaller hatchery fish were captured earlier during this period, leading to disproportionately larger hatchery fish being caught later in the season). It should be noted that the difference in mean size between hatchery and natural Chinook salmon may be underestimated to the extent that unmarked hatchery salmon contributed to the mean length of natural salmon.

3.4.5 Yearling Chinook Salmon

Small numbers of yearling and older juvenile Chinook salmon were collected RM 0 and 18 for length measurements (18 natural and 40 hatchery fish). From mid-February through early April (prior to the release of hatchery yearlings on May 1, 2003), the length of 12 natural Chinook salmon averaged 145 mm, whereas hatchery fish averaged 180 mm. These hatchery fish overwintered in the watershed for one or two winters. Potentially some of these fish captured in the estuary may have originated from other watersheds. Since most Green/Duwamish hatchery Chinook salmon were reported to be clipped in 2001 and 2002 and there is a mean size differential of 35 mm between clipped and unclipped Chinook salmon, a natural yearling life history trajectory is likely being expressed by the unclipped fish. The mean size of non-adipose-clipped yearling Chinook salmon captured after May 1 was 111 mm, compared to the length of recently-released hatchery yearlings, which averaged 110 mm.

3.4.6 Length-Weight Relationship

The relationship between length and weight of subyearling Chinook salmon is shown in Figure 3-24. As expected, weight increased curvilinearly with length. The mean weight of natural Chinook salmon increased from approximately 0.33 g at 40 mm, to 3.6 g at 80 mm, and 7.8 g at 100 mm. Hatchery Chinook salmon exhibited a similar length-weight relationship, but their weight tended to be more variable at a given length. For example, at 80 mm the range in weight of hatchery fish was approximately 4 g to 7 g, whereas the range in weight of natural fish was only 4.2 to 5.8 g. The greater range in weight of hatchery fish, especially near the time of release (e.g. ~80 mm), may reflect greater survival of all body types in the relatively benign hatchery environment.

3.4.7 Scale Pattern Analysis of Subyearling Chinook Salmon

Salmon scale radius and circuli counts are correlated with salmon body length, and analysis of scale patterns can provide valuable information about growth and size at various life stages (Bugaev 1994, Ruggerone et al. and Rogers 2003). In 2003, scales were removed from subyearling Chinook salmon captured at various sampling locations primarily from May 7 through July 23, and a few additional scales were also sampled before and after this period.

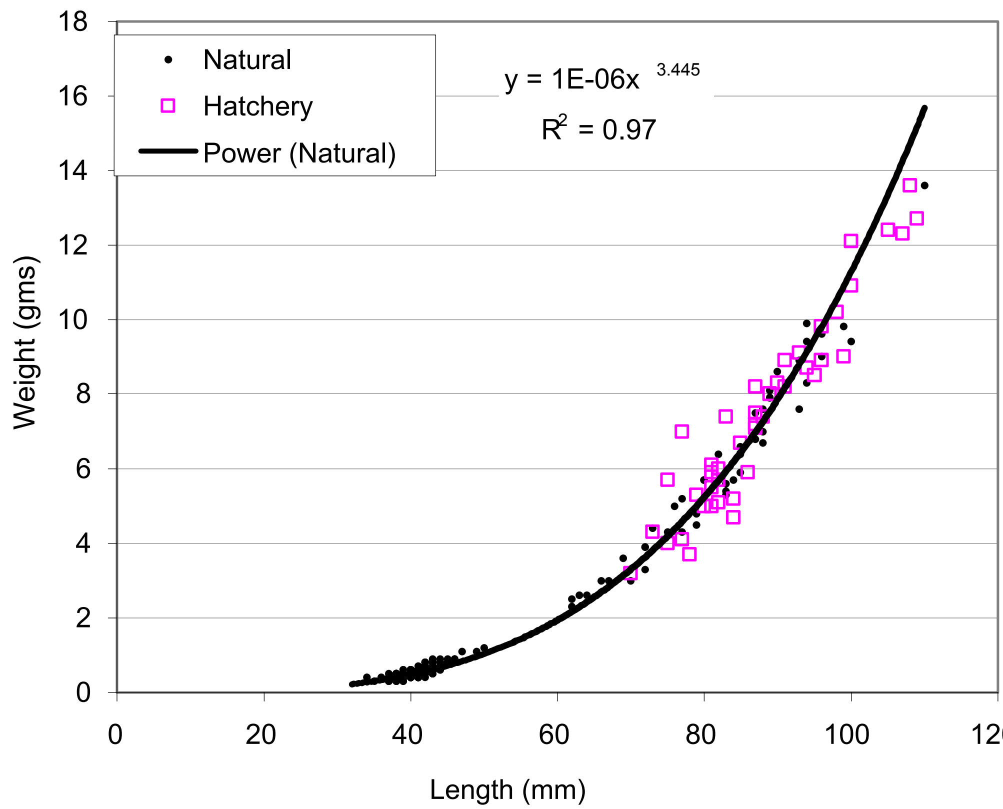


Figure 3-24. Length-weight relationship for natural and hatchery Chinook salmon collected from various locations in the Green River watershed during 2003. Regression equation is shown for natural fish; the relationship for hatchery fish was similar.

Scale measurement data included: (1) the distance from the scale focus to the first "check" (if any), and to the scale edge; and (2) the number of circuli from the scale focus to the first "check" (if any), and to the scale edge. Scale distances were measured to the nearest 0.05 mm. A "check" was defined as an obvious narrowing of two or more circuli. Scale checks are often formed in response to slow growth during winter, and thus a period of slow growth would typically correspond to an annulus. However the checks observed on the scales of these subyearling Chinook salmon were formed during the spring and were not full-scale annuli. Scale checks are generally believed to be formed in response to a significant change and fairly abrupt change in environmental conditions, those resulting from initiation of downstream migration, release from the hatchery, initial entry into marine water, or from other unknown stressors. However, seven hatchery Chinook salmon collected between May 27 and May 29, 2003, exhibited significant growth after the check, as their scales bore an average of 2.8 post-check circuli (range: 1-5 circuli), indicating the check was likely formed while these fish were in the hatchery. Alternatively, the fish might have originated from Chinook salmon plants upstream of Howard Hanson Dam, since some hatchery Chinook, including some individuals with checks, were observed prior to the release of fish from the Soos Creek Hatchery.

As expected, total scale radii increased significantly over time, from approximately 0.269 mm on April 30 to 0.379 mm on July 10. Likewise, total circuli counts increased from 7.5 on April 30 to 13.1 on July 10 (about one circuli per week average). The rate of scale change over time was not markedly different between natural and hatchery salmon (Figure 3-25), but there was considerable variability in the relationship between scale size and statistical week.

The frequency of occurrence of scale checks was significantly greater among hatchery fish compared with natural chinook salmon. On average, 67 percent of the hatchery fish sampled exhibited a check (94 of 140 hatchery fish), whereas only 18 percent natural fish (27 of 146 natural fish) exhibited a check. Distance, number of circuli, and distance per circuli from the scale focus to the first check did not differ significantly between hatchery and natural Chinook salmon (df = 1, 119, $P>0.10$). Likewise, distance, number of circuli, and distance per circuli <u>after</u> the early check did not vary between hatchery and natural Chinook salmon (df = 1, 119, $P>0.15$).

The number of circuli from the scale focus to the early check did significantly increase with statistical week of capture (df = 142, $P<0.001$)[3], although there was considerable variability in the relationships ($R^2 = 0.09$). This finding might reflect either differences in early growth patterns among early versus late migrating fish, or differential size-based mortality (i.e., only the faster growing fish survived to be captured late in the season).

Distance after the early check (hatchery and natural fish combined) increased with statistical week (partial $P<0.001$), and decreased with greater distance from the focus to the early check (multiple regression, partial $P<0.001$, overall $P<0.001$, df = 2, 142, $F = 22.9$, $R^2 = 0.25$). Thus, the post check scale size reflected both age (i.e., statistical week) and the amount of growth prior to the check.

This initial analysis of Green River scale patterns shows that scales can provide useful life history information. It is possible that scale analysis could be used to distinguish early migrating fry from later migrating fingerlings if these fish exhibit unique early growth patterns, but this analysis was not possible with these data because distances between circuli were not measured. Such measurements will require levels of precision much greater than to the nearest 0.05 mm. With greater measurement precision it may also be possible to distinguish hatchery versus natural Chinook salmon.

[3] Sample size was high here because the analysis includes some fish whose origin was unknown (natural or hatchery).

3.4.8 Year 2003 Juvenile Migration Speed

Approximately 42,963 subyearling Chinook salmon were spray marked with one of five colors between February 11 and March 12, 2003, in an effort to estimate migration time from Soos Creek and the Middle Green River (RM 34.5) to the transition zone and estuary (RM 6.5 to 0) (Figure 3-9, Table 3-7). Approximately 9,800 natural Chinook salmon were sampled from the week of February 9 through June 29 in order to detect marked fish.

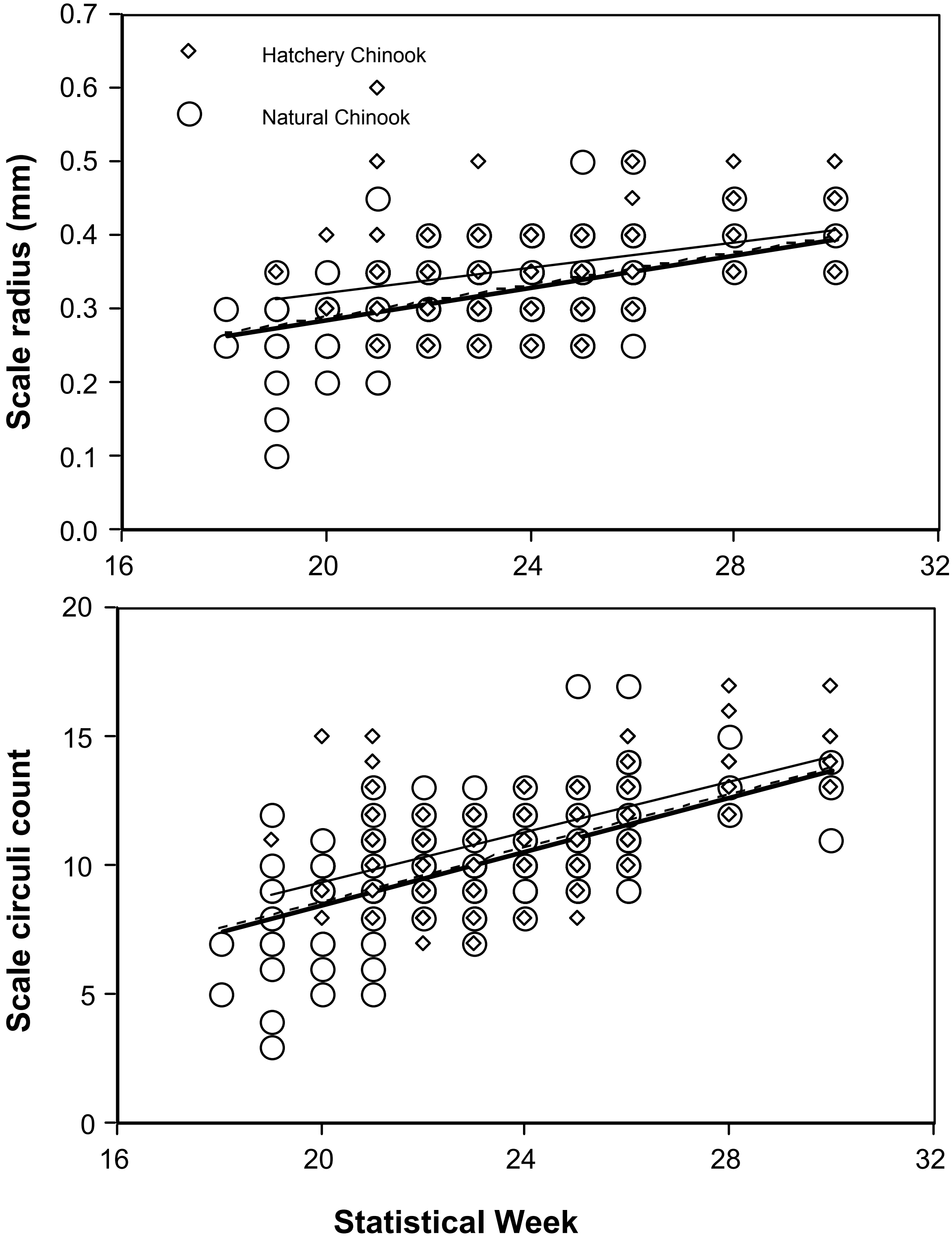


Figure 3-25. Relationship between subyearling Chinook salmon scale radii (upper graph) and scale circuli counts (lower graph) and the statistical week of capture. Data are shown for both hatchery (solid regression line) and natural fish (broken regression line).

Table 3-7. Numbers of natural subyearling Chinook salmon spray-marked and released at Soos Creek and Green River (RM 34.5), 2003.

Release period	Site	Color	No. released	No. recaptured	% recaptured
2/11 - 2/21	Soos Cr	Red	9,781	3	0.031%
2/22 - 2/24	Soos Cr	Blue	12,059	7	0.058%
2/25 - 3/6	Soos Cr	Orange	12,062	5	0.041%
3/11 - 3/12	Soos Cr	Green	5,860	1	0.017%
2/20 - 3/6	Green R	Chartreuse	3,201	1	0.031%
Total			42,963	17	0.040%

A total of 17 of the 42,963 spray marked fish were recaptured, yielding a recovery rate of 0.04 percent. Of these fish, the majority (six fish or 35 percent) migrated to the transition zone (RM 6.5) and downstream areas within one or two days; three fish were recaptured after three to four days, seven fish were recaptured after nine to 18 days, and one fish was recaptured after 31 days (Figure 3-26). The majority of salmon (eight fish or 47 percent) migrated up to three miles per day, but seven fish migrated 12 to 27 miles per day. These values likely underestimate the actual migration rates because some fish could have been present in the sampling area for several days before capture. Potentially, the fish captured after 31 days at large could have spent most of its time in the estuary.

3.5 YEAR 2003 AND 2002 CODED-WIRE-TAG ANALYSES

In 2003, a total of 90 CWT Chinook salmon were captured and analyzed for origin. Of these, 60 (67 percent) originated from the Soos Creek Hatchery. The 30 Chinook salmon originating from non-WRIA 9 watersheds were all captured in Elliott Bay at RM 0, Seacrest, and Alki, except for one fish captured at the Turning Basin at RM 5.5 that came from the Wallace River Hatchery within the Skykomish River watershed. Hatcheries that produced fish captured in the study area in 2003 included the Soos Creek, Wallace River, Issaquah Creek, Gorst Creek, University of Washington, White River Hatcheries and the White Horse Rearing Ponds in the Stilliguamish watershed(Table 3-8). The Wallace River Hatchery contributed 20 percent of the CWT recoveries. These fish migrated 36 miles down the Skykomish and Snohomish Rivers, then at least another 36 miles before capture in the study area. Fish from the other production facilities, which were primarily located in south and central Puget Sound, each contributed three percent or less to the CWT recoveries.

Chinook salmon from other watersheds were captured as early as late May (UW Hatchery), but most were captured during or after the week of June 22. The percentage of recovered CWT Chinook salmon originating from the Green River declined from approximately 80 to 100 percent during the period from late May to mid-June, to 40 percent during late June (10 fish sampled), and finally to zero percent in July (0 of 19 fish sampled; Figure 3-27). In contrast, the numbers of CWT Chinook salmon from other watersheds increased considerably in late June and July. These data suggest that many hatchery fish dispersed well beyond their natal watersheds, leading to extensive juvenile stock mixing in nearshore marine areas. Fish originating in other watersheds were captured, on average, 30 to 35 days after release (Table 3-8). However, some Wallace Hatchery fish arrived in the area within as few as eight days after release.

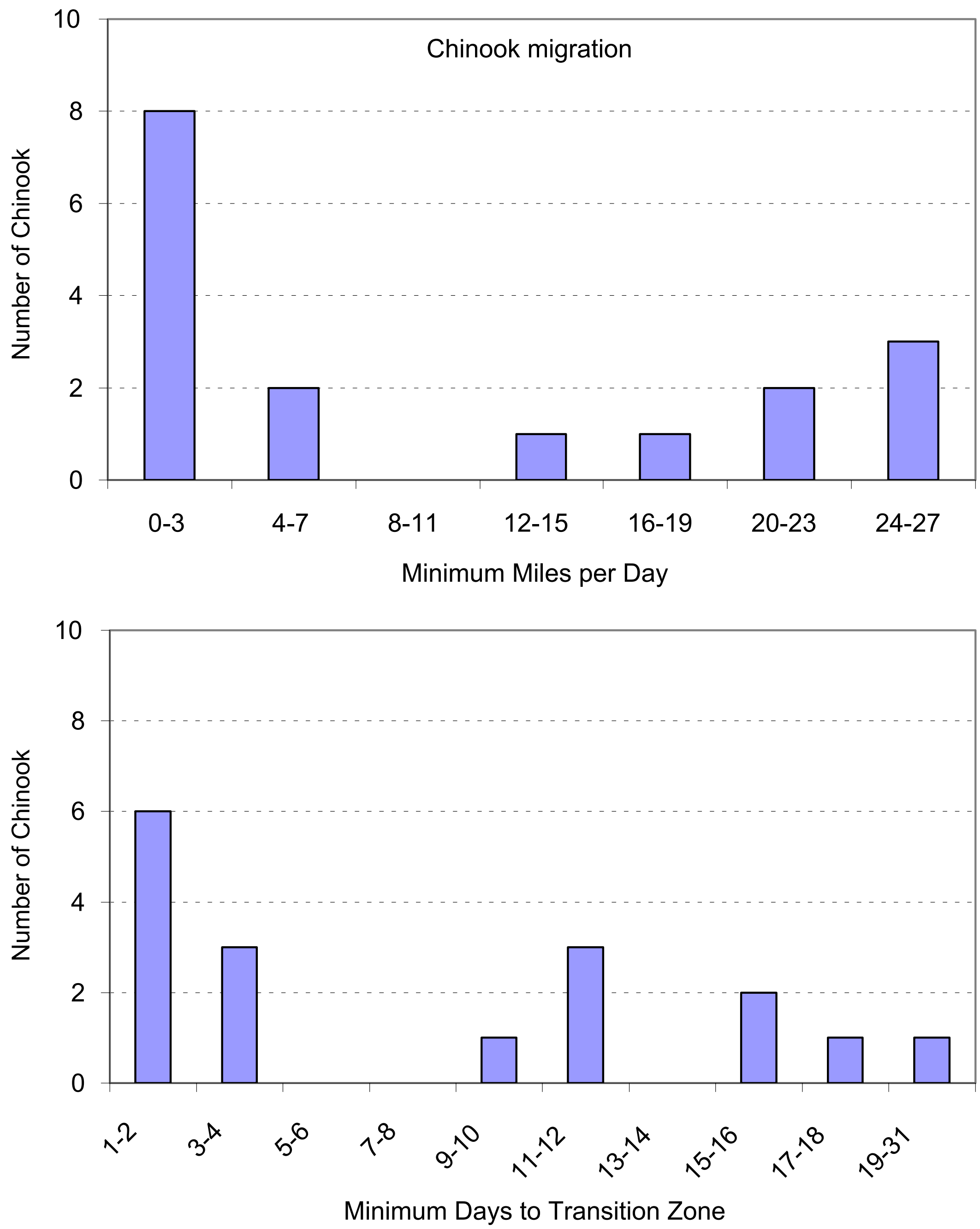


Figure 3-26. Estimated travel time of spray-marked subyearling natural Chinook salmon released in Soos Creek and the WDFW trap at RM 34.5 and recovered at downstream locations.
Note: Travel time calculated as the difference between the weighted mean date of release (five color groups) and the date of recovery at RM 6.5, RM 5.5, RM 13, and RM 2. Approximately 90% of the recoveries were at RM 6.5 and RM 5.5.

Chinook salmon originating from the Green River were captured, on average, approximately 14 days after release at the RM 13 and 5.5 monitoring stations and at the nearshore monitoring stations in Elliott Bay (RM 1 to Alki) (Table 3-9). These fish remained at large a minimum of one day at RM 13 and 5.5, and five days at nearshore marine areas. The maximum number of days at large was 36 at RM 13 and 5.5, and 28 at the Elliott Bay sampling stations. In contrast, yearling coho salmon were captured, on average, 12 to 68 days after release depending on area of capture (Table 3-9). A negative value was produced by five CWT coho salmon captured on April 16 after reportedly being released from Soos Creek on April 20. Presumably some tagged coho had escaped from the hatchery.

In 2003, Chinook salmon marked with both a CWT and a clipped adipose fin (ad-CWT) were captured 50 percent less frequently (20 vs. 40 fish) than fish marked with only a CWT, even though the reported number released was nearly identical (198,324 ad-CWT fish vs. 192,443 CWT only fish). Moreover, these two groups of fish were released on the same day from the same pond and were equal in size (M. Wilson, Hatchery Manager, pers. comm.). Sampling at the RM 18 trap also resulted in the recovery of relatively few ad-CWT fish (48 ad-CWT vs. 75 CWT only fish). Location of capture in the lower river and estuary did not differ between the two groups, but relatively few of the ad-CWT fish were present after early June, e.g., 50 percent of CWT only fish (20 of 40 fish) were recovered after June 5 but only 20 percent of ad-CWT fish (4 of 20 fish) were recovered after June 5. These results suggest that the ad-CWT fish either experienced high mortality soon after release, moved out of the system more quickly, or were incorrectly enumerated at the hatchery. In other words, they had an unusually high rate of poor fin clips, and/or a higher rate of CWT loss. It is interesting to note that this differential recapture pattern was not observed in Green River hatchery Chinook salmon released in 2002, nor among CWT fish recovered from the Wallace Hatchery in 2003. This finding has important implications for the CWT program, at least in regard to the 2003 release from the Soos Creek Hatchery.

In 2002, most juvenile Chinook salmon CWT data were obtained from a study of juvenile Chinook salmon residence time, which was based on otolith chemistry (Ruggerone, unpublished data). This study primarily sampled Chinook salmon at RM 0 and Pier 90/91, but some sampling also occurred at other sites. A few additional CWT data were collected at Kellogg Island, primarily on June 9. In 2002, 133 CWT subyearling Chinook salmon were examined. Of these, 83 (62 percent) originated from the Green River. As in 2003, a large percentage (32 percent) originated from the Wallace River Hatchery, whereas two percent or less were from the Grovers Creek, Hupp Springs, Puyallup Tribe, and the Tulalip Tribe Hatcheries (Table 3-10). All non-Green River fish were captured near Kellogg Island at RM 1, at RM 0, and in nearshore areas in Elliott Bay.

In 2002, the percentage of the total number of CWT Chinook sampled in these areas that bore Green River CWTs declined from 95-100 percent in fish collected in late May and early June, to 60 percent in fish collected in late June, to 22 to 25 percent in July and early August (Figure 3-27). The declining percentages of Green River CWT Chinook salmon reflected a decline in the total number of outmigrating Green River CWT Chinook salmon, and an increase within the lower Duwamish estuarine and Elliott Bay nearshore sampling areas of other CWT stocks during this time period. Although some different stocks were observed in 2002 compared with 2003, the data indicate large numbers of Chinook salmon from other watersheds move into Elliott Bay and the lower Duwamish estuary in late June, whereas Green River fish tend to disperse away from Elliott Bay in early summer.

Among Green River Chinook salmon captured in 2002, the average time from release to capture increased from 1.4 days at RM 5.5 to 6.7 days at RM 1, to 20 days at RM 0 and Pier 90/91 (Table 3-11). Maximum days at large were 5 to 8 days between RM 5.5 to 1, and 34 to 70 days at RM 0 and Pier 90/91 at the north end of Elliott Bay. Two CWT Chinook salmon were captured before the CWT fish were released from the Soos Creek Hatchery, indicating that these fish had escaped before the deliberate release of Chinook salmon from the hatchery.

Table 3-8. Origin of CWT Chinook salmon captured n the study area and time from release to capture, 2003.
NOTE: All fish were subyearling except the yearling from White R. Distance is from mouth of release watershed to mouth of Duwamish.

				Time from release to capture			
Hatchery	Area	Distance (Mi)	N	Avg.	S.D.	Min.	Max
Soos Cr	Green/Duwamish	0	60	14.3	9.3	1	36
Gorst Cr	Sinclair Inlet	19	3	24.3	24.8	10	53
Grovers Cr	Suquamish	16	2	35.0	2.8	33	37
Issaquah Cr	Lk Sammamish	9	3	35.3	7.5	31	44
U. Washington	Lk Washington	9	2	Not available			
Wallace R	Skykomish R	36	18	29.9	8.6	8	37
White Horse	NF Stillaguamish	52	1	Broad release times			
White R	Puyallup R	30	1	Broad release times			

Table 3-9. Days from release to capture of CWT subyearling Chinook salmon and yearling coho salmon released into the Green River watershed, 2003.

		Time from release to capture			
Location	N	Avg.	S.D.	Min.	Max
		Chinook salmon			
RM 13	5	13.4	11.3	7	33
RM 6.5	18	13.8	8.4	1	27
RM 5.5	9	16.3	12.4	7	36
RM 3.5	0				
RM 3.3	0				
RM 1.0	9	10.4	7.7	5	26
RM 0.0	8	18.0	9.7	8	36
Seacrest	8	14.4	8.9	5	28
Alki	3	15.0	10.5	5	26
		Coho salmon			
RM 13	0				
RM 6.5	11	27.8	5.7	17	38
RM 5.5	13	11.7	10.1	4	24
RM 3.5	5	-4.0	0.0	-4	-4
RM 3.3	9	22.2	0.4	22	23
RM 1.0	3	34.7	20.2	23	58
RM 0.0	1	68.0		68	68
Seacrest	1	30.0		30	30
Alki	0				

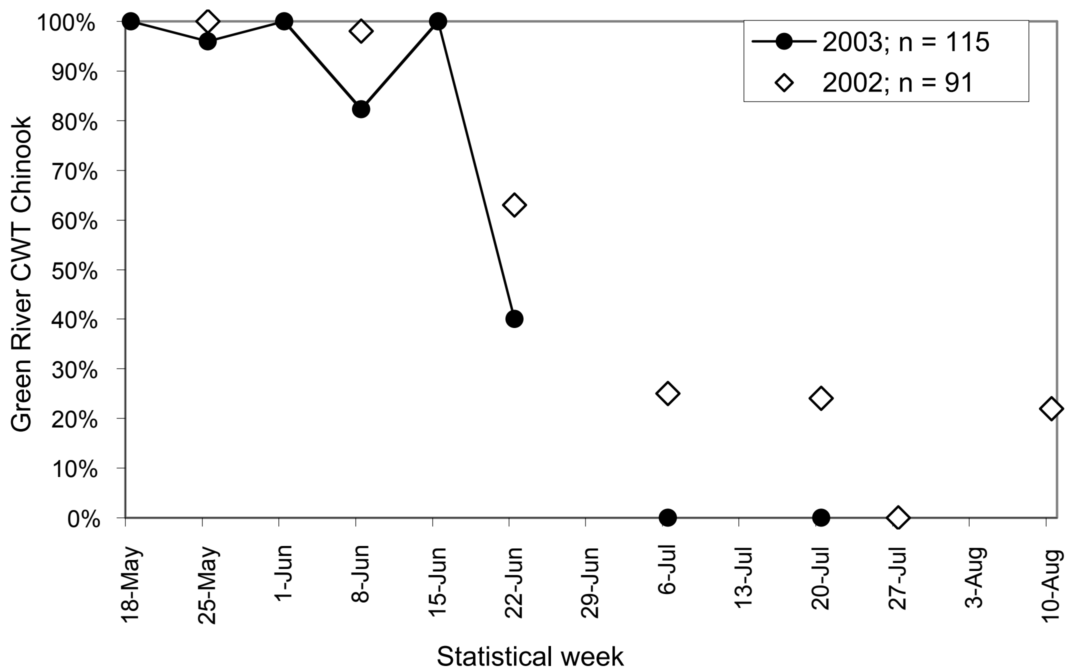


Figure 3-27. Percentage of CWT subyearling Chinook salmon captured in the study area (Elliott Bay and Duwamish) that originated from the Green River in 2002 and 2003.
NOTE: Total CWT observed each year are shown. All values based on 6 or more fish, except in May and July 27, 2002.

Table 3-10. Origin of CWT Chinook salmon captured in the study area and time from release to capture, 2002. All fish were subyearling Chinook salmon. Distance is from mouth of release watershed to mouth of Duwamish.

				Time from release to capture			
Hatchery	Area	Distance (Mi)	N	Avg.	S.D.	Min.	Max
Soos Cr	Green/Duwamish	0	83	12.4	15.0	-5	70
Grovers Cr	Suquamish	16	3	37.3	9.2	32	48
Hupp Springs	South Sound		1	50.0			
Puyallup Tribe	Puyallup	30	3	75.0	12.1	61	82
Tulalip Tribe	Snohomish	36	1	27.0			
Wallace R	Skykomish R	36	42	31.6	18.9	9	111

Table 3-11. Days from release to capture of CWT subyearling Chinook salmon released into the Green River watershed, 2002. Only fish at RM 0 and Pier 90/91 were sampled consistently for CWT during study period because they were primary sites for otolith-based residence time study.

		Time from release to capture			
Location	N	Avg.	S.D.	Min.	Max
RM 5.5	11	1.4	5.0	-5	5
RM 1	31	4.8	2.4	-4	8
RM 0	31	21.7	18.9	5	70
Pier 90/91	10	19.6	9.7	5	34

3.6 *YEAR 2002 CHINOOK SALMON ABUNDANCE AND MIGRATION TIMING NATURAL SUBYEARLING CHINOOK SALMON*

3.6.1 Natural Subyearling Chinook Salmon

At the RM 34.5 trap, the temporal migration pattern of subyearling natural Chinook salmon during winter through early summer was bimodal. Chinook juveniles were relatively abundant at this monitoring station from mid-February through late April (Figure 3-28). Peak catches of Chinook salmon (~425 Chinook fry per day) occurred during mid-March, before declining to an average of only 23 fish per day from late April through late May. Then from early June through early July, juvenile Chinook salmon

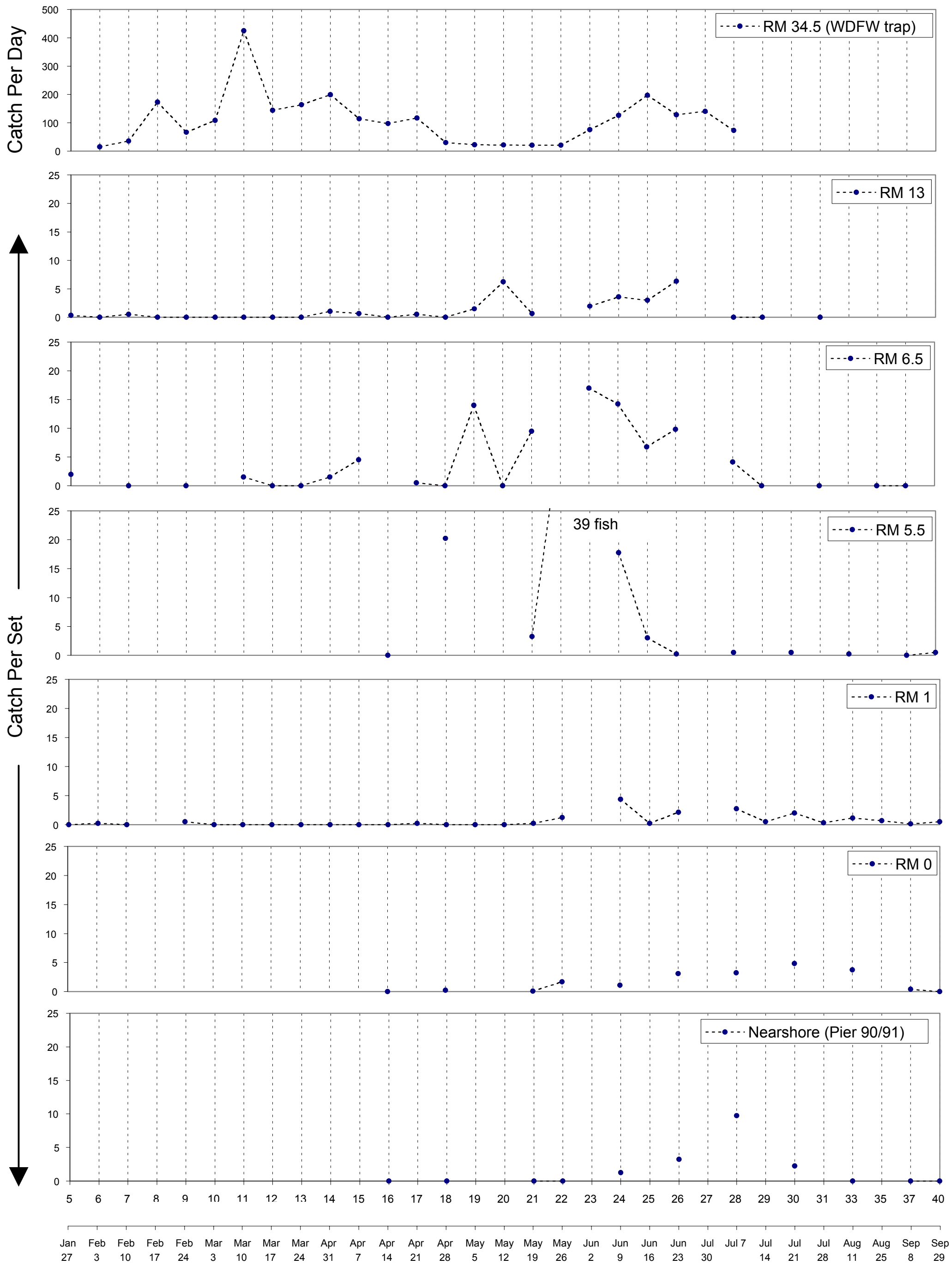


Figure 3-28. Mean catch per beach seine set of <u>natural</u> subyearling Chinook salmon in the Green/Duwamish watershed and nearshore marine habitat, 2002. All fish captured by beach seine, except those at RM 34.5 (screw trap). Samples collected with the Puget Sound Protocol net (primarily RM 0, 2, 5.5, and nearshore) were reduced by 50% in order to standardize CPUE with the smaller river seine (see text and Appendix).

catches increased to an average of 123 per day, before declining again toward the end of the outmigration season. A weak bimodal migration pattern was observed in 2003, but the proportion of fingerlings outmigrating in late May and June 2003 was smaller. The total catches of juvenile Chinook salmon in 2002 (17,600 fish) were similar to those in 2003 (17,800 fish), but 70 percent less than catches in 2001 (56,300). A more accurate comparison of total juvenile Chinook salmon abundance will become available when WDFW applies trap efficiency values to the catch statistics for 2001, 2002, and 2003 and calculates the total population size.

In contrast to 2003, the relatively large migration of subyearling Chinook fry at the RM 34.5 trap during late winter and early spring of 2002 was not observed at RM 13, in the estuarine transition zone at RM 6.5, or in the lower estuary at RM 1 near Kellogg Island (Figure 3-28). Sampling effort was also less frequent in 2002 compared with 2003, but it should have been sufficient to detect a large movement of fry during late winter and spring, if it had occurred. Catches during late January through early April of 2003 were also typically less than two subyearling Chinook salmon per set.

During early May through June, relatively large catches (mean weekly catches of up to 39 fish per set) of Chinook salmon occurred at RM 13, RM 6.5, and RM 5.5, but catches declined to less than five fish per set from July through September. Small numbers of natural Chinook salmon were still present in the estuary (e.g., between RM 5 and 1) during late September. Peak catches of Chinook salmon at RM 1 and RM 0 occurred later in the season (e.g., from late June to early August) compared with upstream areas, but catches were small, typically fewer than five fish per set.

One possible explanation for the interannual variation in juvenile Chinook salmon abundances over the course of this study could be high mortality of incubating eggs in 2002 due to high flows. In 2002, from mid November to the first week in January, a series of at least three high flow events occurred, each ranging from 6,000 to 7,000 cfs as measured at Auburn. In 2003 during the same egg incubation period, high flows did not exceed 1,700 cfs. In 2003, large flood flows occurred in early February, possibly decreasing survival of late emerging fry that contributed to late migrating fingerlings in 2003.

In 2002 catches of subyearling Chinook salmon were considerably greater within the Duwamish transition zone, between RM 6.5 and RM 5.5, compared with catches at RM 13 and those near the mouth of the river and in the Elliott Bay nearshore (Figure 3-28). During the period of peak salmon abundance (May through mid-June), average catch per set at RM 6.5 and RM 5.5 represented approximately 87 percent of the cumulative catch per set in the study area (i.e., the total catch in the Elliott Bay nearshore, and at RM 0, RM 1, RM 5.5, RM 6.5, RM 13). Catches at RM 13, which amounted to seven percent of the total catch, were greater than those in the lower estuary at RM 0 and RM 1, and the nearshore marine area. However, beginning in mid-July, relatively few Chinook salmon were captured at RM 13 and RM 6.5 compared with catches at downstream areas. The finding of relatively large catches at RM 5.5 and RM 6.5 during the peak of the migration period was consistent with results in 2003. The high catches in this transition zone area indicate many fry hold in this area for a longer period compared with adjacent areas both upstream and downstream.

3.6.2 Hatchery Subyearling Chinook Salmon

Approximately 3.5 million hatchery subyearling Chinook salmon were released from the Soos Creek Hatchery from May 23 to June 7, 2002 (Table 3-12). Approximately 94 percent of the release occurred on or after May 30. The somewhat late timing of these releases was related to relatively cool water temperatures and reduced fish growth in 2002 (Wilson 2002). An additional 0.5 million subyearling Chinook salmon were released by the MIT upstream of Howard Hanson Dam (Table 3-13) in 2002. Based on a survival rate estimated in 2000 by Seiler et al. (2002), it can be assumed that approximately 3.7 percent of these fish successfully migrated through Howard Hanson Dam in 2002, and as a result, an additional 18,500 adipose fin-clipped subyearling Chinook salmon outmigrated through the river and estuary from late March through mid-June.

Peak catches of hatchery subyearling Chinook salmon occurred during late May through mid-June (Figure 3-29) of 2002. The largest catches occurred at RM 1, RM 5.5, and RM 6.5 where up to 160 hatchery fish per set were obtained. Peak catches were relatively small (<25 fish per set) at RM 13, RM 0, and in the Elliott Bay nearshore at Pier 90/91. In the river and estuary, catches of hatchery Chinook salmon declined to less than five per set in early July. In the nearshore at Pier 90/91, small catches occurred after late July, indicating that some hatchery fish remained in the area for a month or more. Analysis of CWT hatchery salmon indicated some of these fish had originated from other watersheds. Small numbers of hatchery Chinook salmon (mostly from the Soos Creek Hatchery, but potentially some from marked releases upstream of Howard Hanson Dam) remained in the estuary until at least mid-August. The catch data suggest that the majority of hatchery Chinook salmon spent two weeks or less in the lower watershed.

The large release of hatchery Chinook salmon is shown by the sharp decline in the percentage of natural subyearling Chinook salmon among the total Chinook salmon sampled. During the peak of the hatchery Chinook salmon migration, the percentage of natural Chinook salmon in the catches declined to approximately 20 percent at RM 13, 10 percent at RM 6.5, five percent at RM 5.5, three percent near Kellogg Island, five percent at RM 0, and 17 percent in the nearshore marine area (Figure 3-30). The lowest percentages of natural Chinook salmon occurred during the weeks of June 3 and June 10 (these observed minima occurred later at the lower sites), which was a period of peak abundance of natural Chinook salmon in 2002. Thereafter, the percentage of natural Chinook salmon increased in late June and July as the hatchery fish moved out of the system. It is likely that the percentage of natural Chinook salmon was overestimated because approximately three percent of the 3.5 million hatchery Chinook salmon (100,000 fish) did not receive an adipose fin clip or a CWT tag, and thus would have been incorrectly identified as naturally-produced salmon. However, after mid-August no marked Chinook salmon were captured at several of the Duwamish monitoring sites (RM 5.5, RM 1, and RM 0), suggesting that few hatchery Chinook salmon remained in the Duwamish by late summer.

Table 3-12. Salmon and steelhead releases by the Green River Hatchery complex, 2002. Source: Trudy, Assistant Hatchery Manager, pers. comm.

				Number Released			%		
Species	Age	Location	Release Date	Ad+CWT	CWT only	AD only	bad clip	wt (g)	Comment
Chinook	subyearling	Soos Cr	23-May	0	0	198,100	3%	5.7	Some treated for furnunculosis
Chinook	subyearling	Soos Cr	30-May	0	0	194,700	3%	5.7	
Chinook	subyearling	Soos Cr	30-May	0	0	199,900	3%	5.7	
Chinook	subyearling	Soos Cr	31-May	0	0	199,200	3%	6.0	
Chinook	subyearling	Soos Cr	1-Jun	0	0	239,600	3%	5.7	
Chinook	subyearling	Soos Cr	3-Jun	66,387	67,742	726,071	3%	6.7	
Chinook	subyearling	Soos Cr	5-Jun	67,191	67,066	694,243	3%	5.4	
Chinook	subyearling	Soos Cr	7-Jun	55,300	66,059	686,341	3%	6.4	
			Totals	188,878	200,867	3,138,155	99,811		
Chinook	yearling	Icy Cr	volitional: May 7-May 24		0	300,000	~1%		
Coho	yearling	Soos Cr	6-Apr	45,000	45,000	510,000	?	26.7	
Steelhead	yearling	Soos Cr	2-May		0	29,000	?	100.8	
		Palmer	volitional: May 1		0	96,000	?	75-100	
		Icy Cr	volitional: May 1-May 24		0	40,000	?	75-100	
		Flaming Geyser	3-May		0	15,000	?	75-100	
			Totals			180,000			

Table 3-13. Salmon and steelhead releases into the Green River watershed by the Muckleshoot Indian Tribe, 2002. Source: Dennis Moore, MIT Hatchery Manager, pers. comm..

				Number released						
Species	Age	Date	Location	Ad+CWT	CWT only	AD only	No mark	% bad clip	Wt (g)	Comment
Chinook	subyearling	March 20-25	Above H. Hanson Dam			402,000		~5%	2.5	No CWT, no yearlings released; clip retention not quantified, but may be similar to Soos Cr (Moore, pers. comm.)
Coho	subyearling	April 14-15	Above HH				548,000	NA	1.0	
Coho	yearling	April 30-May 7	Crisp Cr				240,000	NA	29.5	
		April 30-May 7	Crisp Cr	11,000				?	29.5	96.6% CWT retention on both groups
		April 30-May 7	Crisp Cr		39,000				29.5	
Coho	yearling	~June 1	Myrtle Edwards Net Pens				352,000			Goal is 400,000 total
			Myrtle Edwards Net Pens	50,000	(included in 50K)			?		Paul Dorn, Suquamish Tribe
			Totals:	61,000	39,000		1,140,000			
						Grand total:	1,240,000			
Steelhead	yearling	April 30-May 7	Keta Cr			34,000		?	82.5	Green R Native spawn in hatchery
						Ad/left ventral (pelvic)				
Chum	subyearling	March 7-April 7	Keta Cr				1,200,000	NA	1.0	No marks

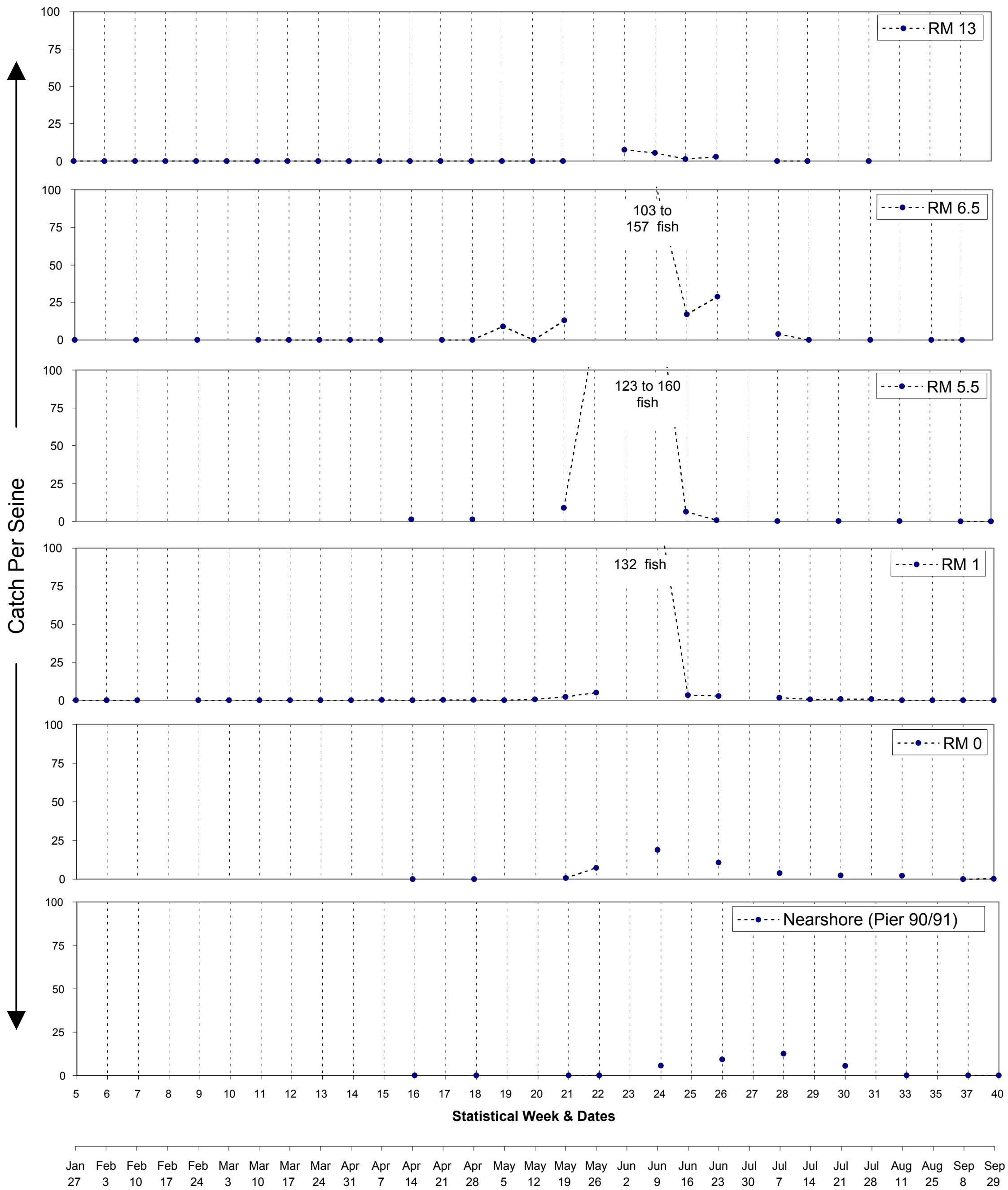


Figure 3-29. Mean catch per beach seine set of <u>hatchery</u> subyearling Chinook salmon in the Green/Duwamish watershed and nearshore marine habitat, 2002. Samples collected with the Puget Sound Protocol net (primarily RM 0, 2, 5.5, and nearshore) were reduced by 50% in order to standardize CPUE with the smaller river seine (see text and Appendix E).

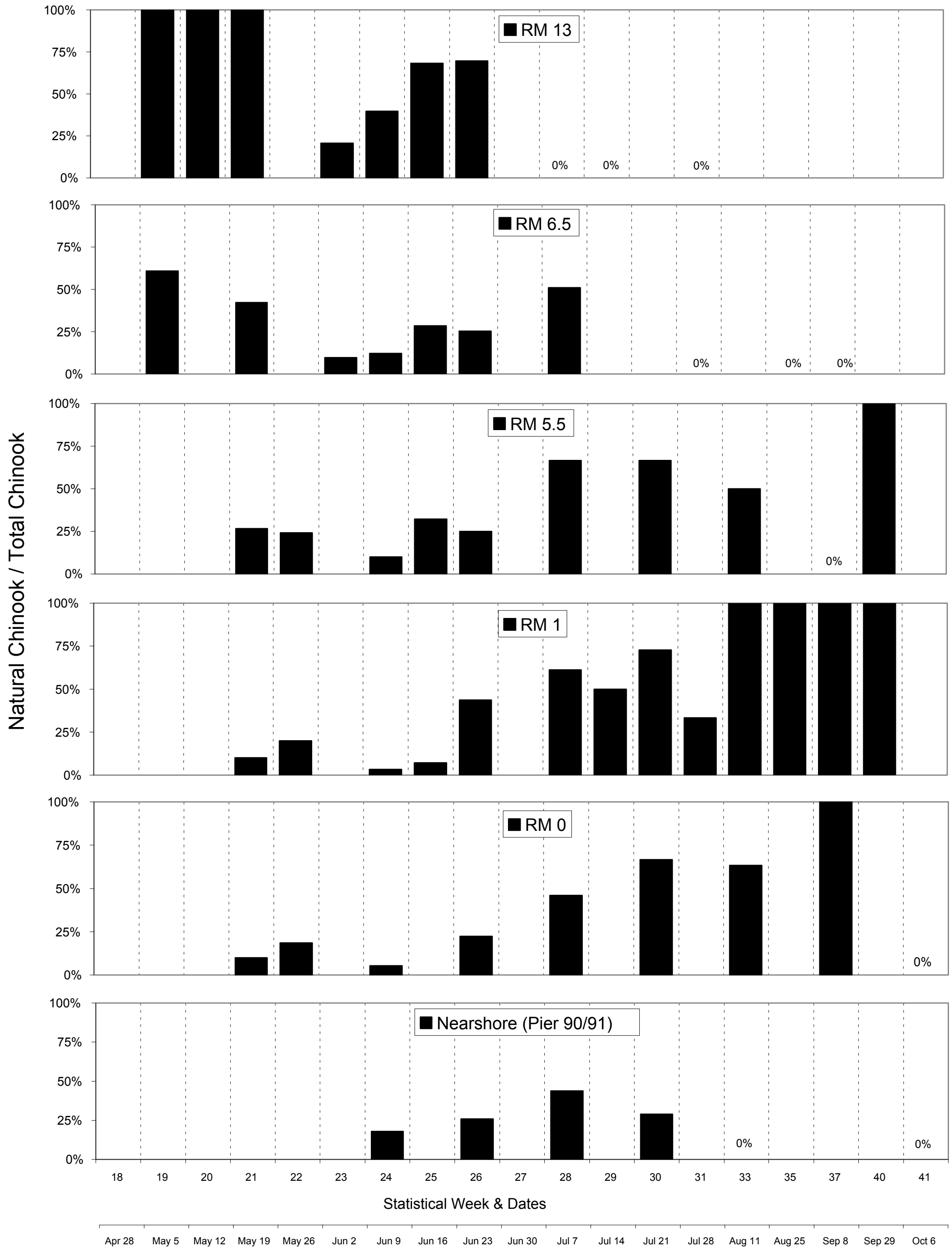


Figure 3-30. Percentage of natural subyearling Chinook salmon among total catch of subyearling Chinook salmon, 2002.
Some hatchery fish were observed prior to the WDFW first reported release of hatchery subyearling chinook on May 23. Apparently, these fish escaped through screens at the hatchery.

3.6.3 Yearling Chinook Salmon

A total of 15 natural (unmarked) and 81 hatchery yearling and older Chinook salmon were captured by all gear types in 2002. Three older natural Chinook salmon averaging 196 mm in length were captured in late January at RM 6.5, seven natural yearlings averaging 109 mm were captured in late April between RM 0 and 5, and five natural Chinook salmon averaging 145 mm were captured from late May through mid-June between RM 13 and 1. Almost all hatchery fish were reported to have been adipose clipped in 2001, so these fish could be indicative of a natural yearling life history trajectory. In addition, some of the older, larger Chinook salmon captured in the Duwamish could have emigrated into the Lower Green/Duwamish River and estuary from a different watershed.

Approximately 300,000 hatchery yearling Chinook salmon were released from the Icy Creek rearing ponds between May 7 and May 24, 2001 (Tables 3-12 and 3-13). While approximately 70 percent of the 81 hatchery Chinook sampled in 2001 were captured within or soon after the release period, five fish were captured as late as June 14, indicating that some hatchery yearlings resided in the system for at least three weeks after release. Most hatchery yearlings were captured at RM 5.5 and RM 1, and averaged 161 mm in length.

Twenty-three yearling and older hatchery Chinook salmon were captured during late January through late April, a period that preceded the hatchery release from Icy Creek. These fish may have originated from subyearling hatchery Chinook salmon planted by MIT in 2001 either upstream of Howard Hanson Dam, or those released below the weir at the Soos Creek hatchery. These data indicate that some hatchery fish overwinter in the Green River watershed. All of these fish were captured between RM 6.5 and RM 0, and they averaged 175 mm in length.

3.6.4 Other Salmonids

Other salmonids captured in the study area included 2,665 chum fry, 106 natural coho, 378 hatchery coho, 27 pink fry, 16 natural steelhead, 53 hatchery steelhead, one cutthroat trout, and seven unidentified trout. These species were much less abundant than the 1,192 natural and 1,750 2,750 hatchery Chinook salmon captured during 2002.

3.7 *YEAR 2002 CHINOOK SALMON SIZE*

3.7.1 Natural Subyearling Chinook Salmon

Size of natural subyearling Chinook salmon was examined from February through mid-July, 2002. Fork length data (live measurements) were collected on a weekly basis at the RM 34.5 WDFW screw trap, and less frequently at RM 13, RM 6.5 to RM 0, and at Pier 90/91 in Elliott Bay.

At RM 34.5, the length of Chinook salmon increased slowly from a mean length of 40 mm in February and a mean length of 42 mm through early April, (42 mm), before rapidly increasing to mean lengths of 59 mm in early May, 67 mm in early June, and 80 mm in early July (Figure 3-31). The relatively low increase in size during winter and early spring reflects the continued capture of recently emerged fish, and relatively slow growth due to the prevailing cold water temperatures, and possible scarcity of food. Fish sampled at the WDFW trap tended to be smaller on a given date than measured downstream, because they were closer to the spawning grounds, and presumably had emerged from the gravel fairly recently.

The mean length of subyearling natural Chinook salmon sampled between RM 6.5 and RM 0 increased from approximately 46 mm in early April, to 51 mm in early May, 74 mm in late May, 81 mm in late June, and 94 mm in late June (Figure 3-32). These growth kinetics reflect a combination of growth, and net movement of fish into and out of the study area. While noting this potential bias, we calculated an index of growth based on the change in mean size over time. Healey (1991) estimated that this approach, which has been applied in a number of studies of juvenile salmonid utilization of estuarine habitat, tends to underestimate growth by approximately 50 percent, based on comparisons with studies using marked salmon.

Fewer data were available in 2002, compared with 2003, for evaluation of the growth rate of natural Chinook salmon. Daily growth of Chinook salmon between RM 6.5 and RM 0 ranged from 0.39 to 0.90 mm (mean: 0.66 mm) during May, prior to the release of most hatchery salmon (Figure 3-33). Insufficient size data were available during the first week in June, when 78 percent of the total hatchery Chinook salmon were released, but daily growth during the second week of June declined to the lowest value of the season, 0.14 mm per day, before increasing slightly to 0.29 mm per day during the last two weeks of June, and to approximately 0.44 mm per day in July. Daily growth at RM 13 during the first two weeks in June averaged 0.5 mm per day, an intermediate value compared to the growth rates calculated for period between the beginning of May and mid-June at RM 6.5 to RM 0, 0.66 to 0.14 mm per day.

Daily growth between RM 6.5 and RM 0 also declined in 2002 after the release of 3.5 million hatchery Chinook salmon. However, daily growth of subyearling Chinook salmon at RM 34.5, which is upstream of the hatchery, also declined during this time period from approximately 0.57 mm per day in late May and early June, to 0.38 mm per day from mid-June to mid-July (Figure 3-33). During May, the mean length of Chinook salmon was 8.5 mm longer between RM 6.5 and RM 0, compared with the mean length of fish sampled at RM 34.5, but this difference declined to 1.6 mm during June. Fish sampled at RM 13 were consistently smaller than those sampled between RM 6.5 and RM 0. These data suggest that the reduction in growth observed between RM during 2002 was likely influenced by the observed increase in the migration of somewhat smaller fingerlings from the Middle Green River in June (Figure 3-28).

3.7.2 Hatchery Subyearling Chinook Salmon

The mean size of hatchery Chinook salmon was 13.2 mm greater than that of natural fish over the same time period at RM 13, 6.6 mm greater between RM 6.5 and RM 0, and 9.8 mm greater in the Elliott Bay nearshore (Figure 3-32). Nevertheless, there was considerable overlap in the size range of the two stocks, emphasizing the importance of adipose fin marking for visual identification. Between RM 6.5 and RM 0, the daily growth of hatchery salmon declined steadily from late May (0.38 mm) through mid-June (0.18 mm), then increased slightly to 0.29 mm in late June (Figure 3-34). In July and August, when few fish were present, daily growth increased to 0.60 mm and 0.92 mm, respectively. Calculated daily growth at RM 13 was negative in mid-June[4], and then increased to moderately low levels in late June. Daily growth of hatchery salmon during late May and June (0.27 mm) tended to be lower than that of natural salmon (0.41 mm). As in 2003, the high density of hatchery salmon may have increased intraspecific competition, thereby reducing growth, especially of the smaller-sized natural chinook. Alternatively, the low growth rate could be explained by relatively fast emigration of larger individuals.

[4] The negative growth estimate is an artifact of non-random sampling of the population. Nevertheless, the value suggests growth was somewhat low.

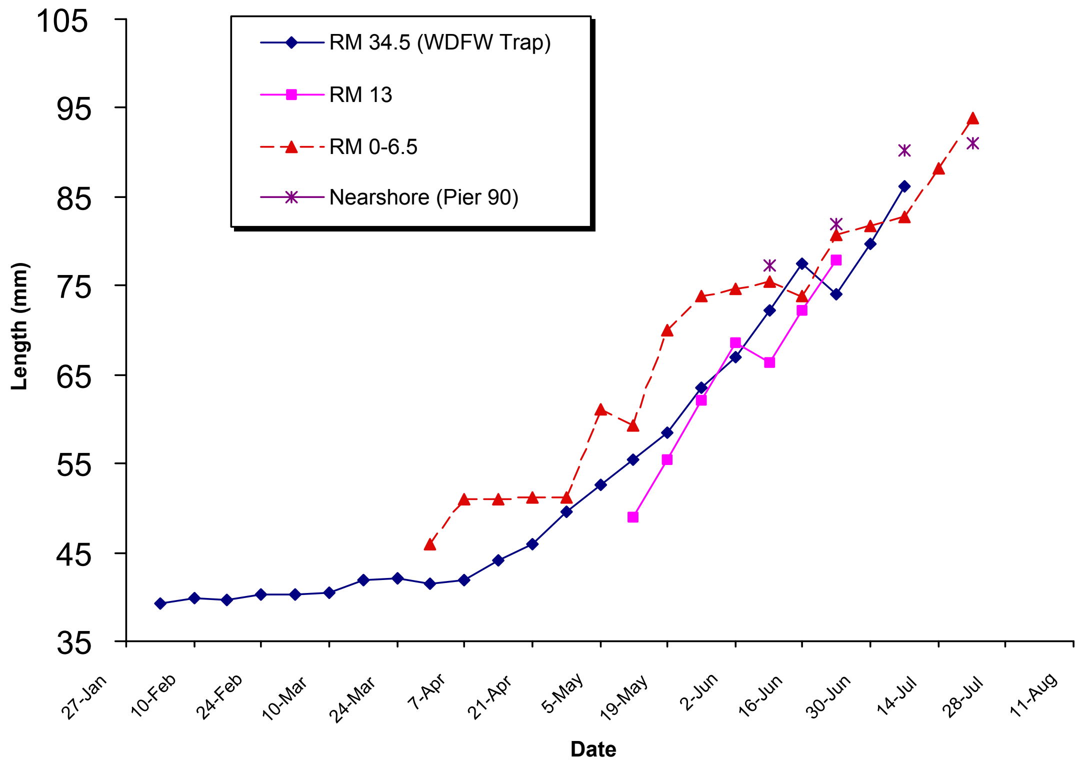


Figure 3-31. Mean length (mm) of natural subyearling Chinook salmon by location and week, 2002.

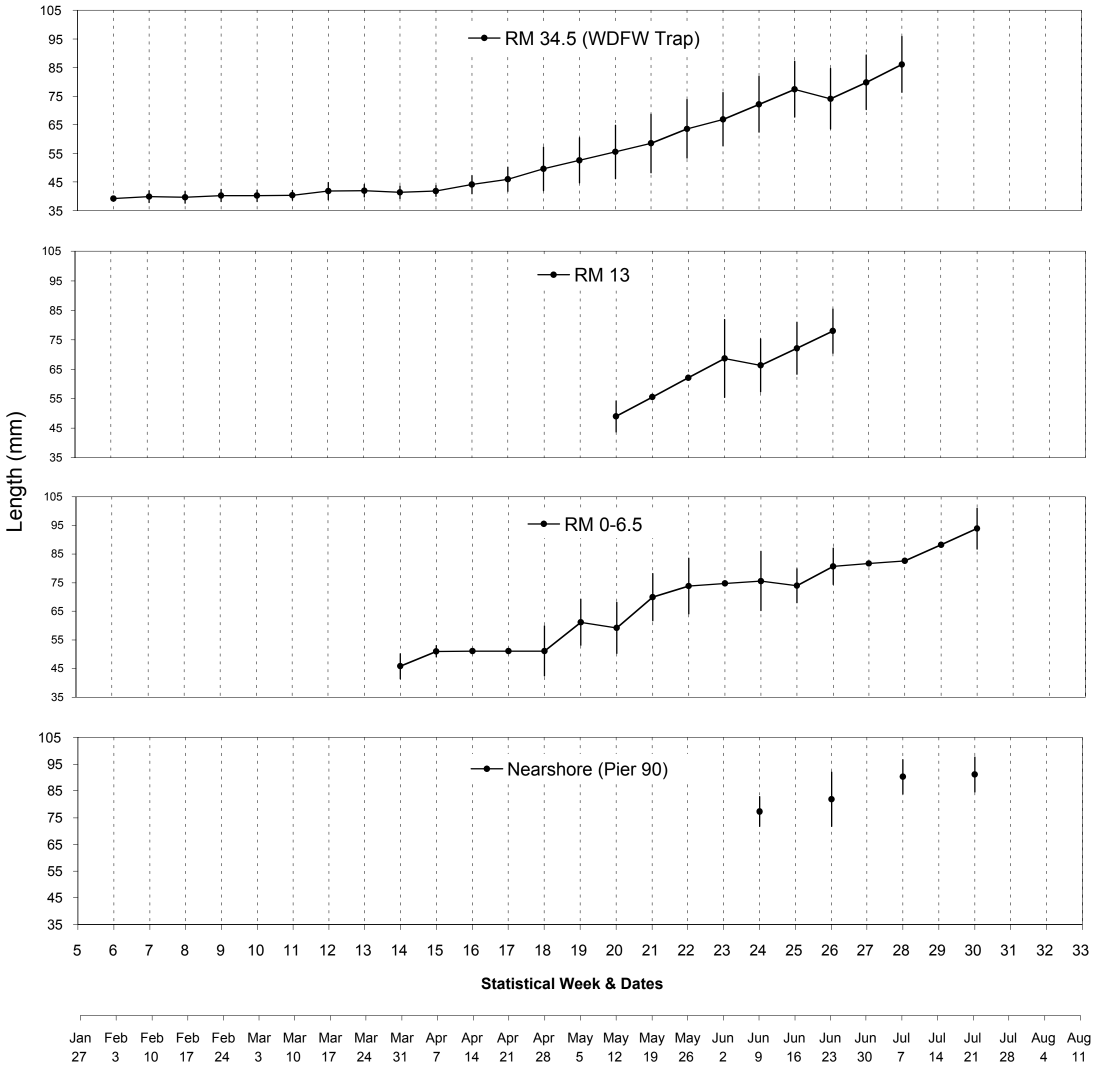


Figure 3-32. Mean length (± 1 SD) of natural subyearling Chinook salmon by location and week, 2002.

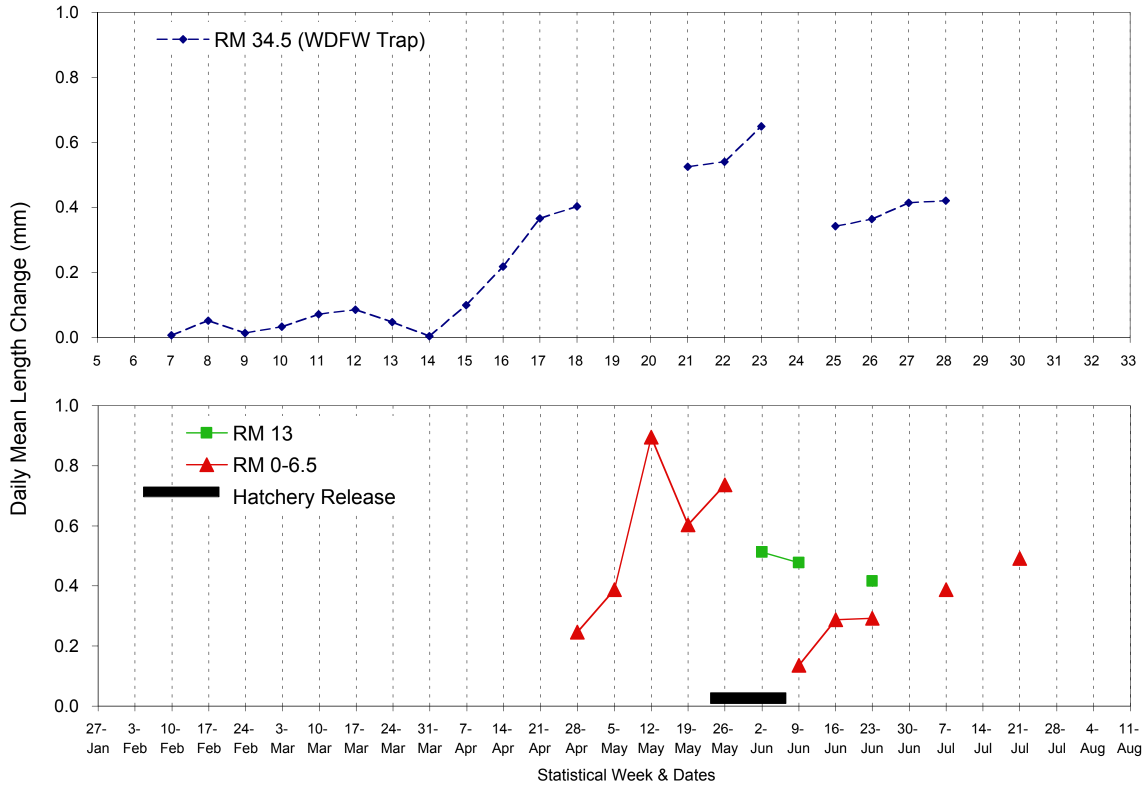


Figure 3-33 Daily change in mean length (mm) of natural subyearling Chinook salmon at RM 34.5, RM 13, and RM 0-6.5 during February through July 2002. Estimates based on 25 or more fish per week.

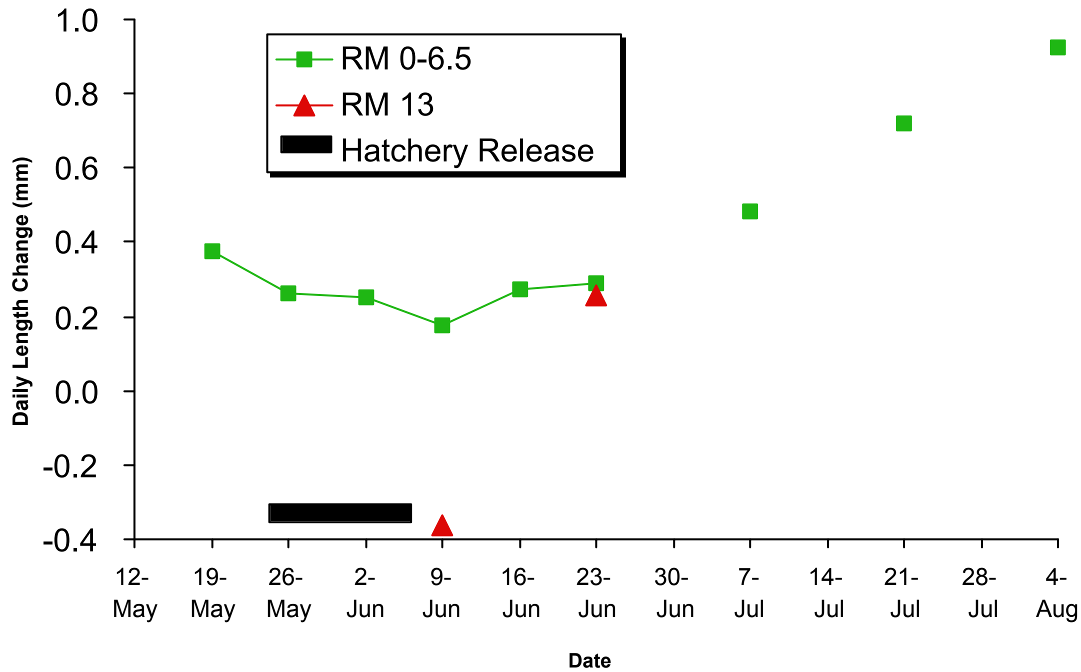


Figure 3-34. Daily change in mean length (mm) of hatchery subyearling Chinook salmon (on vertical axis) at RM 13 and RM 0-6.5 during late May through early August, 2002.
Estimates based on 25 or more fish per week.

3.7.3 Yearling Chinook Salmon

See discussion of yearling lengths in Abundance and Migration Timing Section.

3.7.4 Yearling Chinook Salmon Acoustic Tag Tracking Pilot Study.

On May 30, eight days after tag implantation, the two-person crew aboard the project skiff detected a 72kH signal at 10:12 a.m. using a portable Vemco VR60 ultrasonic receiver. The signal emanated from waters near the northern end of East Duwamish Waterway, later in the day, at 3:10 PM, at from waters near north end of Harbor Island in Elliott Bay. Although the signal rate was not what was expected, the 72kH acoustic transmission definitely matched that of the transmitter implanted into the 207-mm Chinook, thus was assumed to be from that fish. The signal rate may have changed due to battery failure or other mechanical problem. The 75kH signal was never detected from the other tagged fish and its fate is unknown.

The pilot study showed that yearling hatchery Chinook salmon could be successfully tagged at a 207 mm size and recovered about 50 miles downstream, several days after implantation.

3.7.5 Subyearling Chinook Salmon Passive Integrated Transponders (PIT) Tag Migration Pilot Study

WDFW staff tagged 1,041 hatchery and 207 wild Chinook salmon during this study. The JSSS staff recovered one PIT-tagged Chinook salmon on June 20 at the Trimaran site, 13 days after release from the hatchery. The fish had grown in fork length from 79 to 84 mm, implying a growth rate of 0.38 mm per day. USACOE staff recovered two more PIT-tagged fish on June 11 and 12 near Kellogg Island, but measurements were not recorded. ACOE staff estimated that about 6,400 fish would have to be PIT-tagged in order to recovery 20 fish. This estimate is based on the level of effort expended in 2002. ACOE staff concluded that the recapture rate was too low to warrant the expense of future PIT-tagging studies on the Green/Duwamish River.

3.8 YEAR 2001 CHINOOK SALMON ABUNDANCE AND MIGRATION TIMING

3.8.1 Natural Subyearling Chinook Salmon

Sampling in 2001 was limited to the WDFW screw trap at RM 34.5 and to beach seining at RM 13. Sampling at RM 13 was conducted in a pilot study to evaluate the site for future, more intensive sampling and to test the efficacy of the river beach seine for possible use in the expanded sampling program planned for 2002 and 2003 (Nelson and Boles 2003). Data are presented here for comparison with data collected in 2002 and 2003.

At RM 34.5, the temporal migration pattern of natural subyearling Chinook salmon was bimodal, and the early peak migration of relatively small “fry migrants” was the most abundant component of the migration. Relatively few natural subyearling Chinook salmon were captured from late January through late February (avg. 57 fish per day), but catches increased sharply during in February and continued to be quite robust through March (avg. 935 per day) (Figure 3-35). Catches declined abruptly to an average of 37 salmon per day during mid-April to early May, then increased again in mid-May through mid-June (avg. 440 per day). Thereafter, catches declined, on average, to 25 fish per day during late June through July.

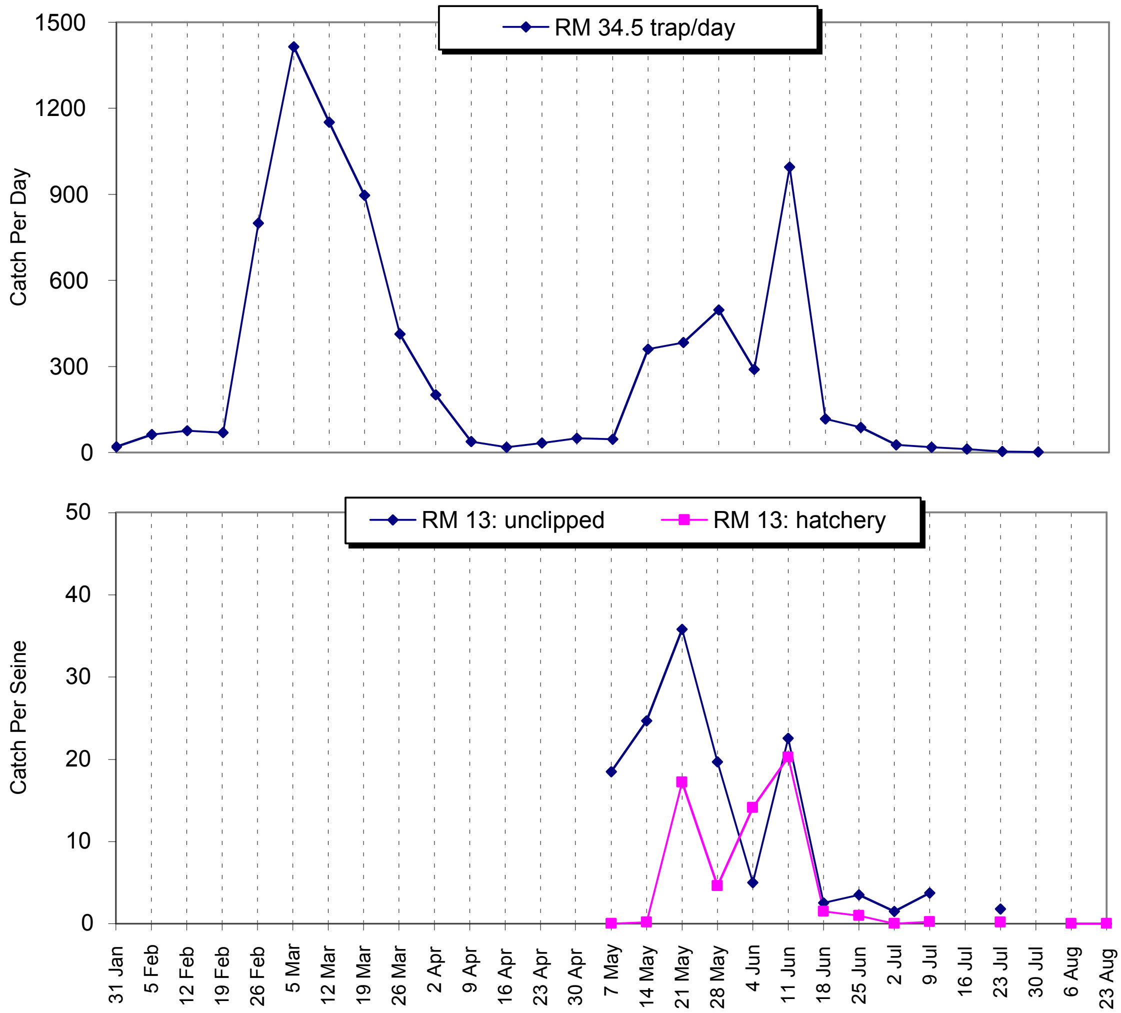


Figure 3-35 Catch per day of natural subyearling Chinook salmon at the RM 34.5 screw trap (upper graph) in comparison with catch per beach seine set at RM 13 (lower graph), 2001.
An unknown number of unclipped hatchery Chinook salmon were captured at RM 13 after the initial release on May 18.

Fishes were sampled at RM 13 from May 8 to August 23, 2001. Prior to hatchery releases, which began on May 18, catches of natural Chinook salmon averaged 22 fish per set (Figure 3-35). Thereafter, an unknown percentage of unmarked hatchery likely formed a component of relatively high catches of unmarked salmon, because approximately 255,000 unmarked subyearling hatchery Chinook salmon were released during late May, and a CWT detection wand was not available for use in processing catches that undoubtedly included some of the approximately 200,000 unmarked fish that received a CWT at the hatchery (Tables 3-14 and 3-15). Although population estimates of natural juvenile Chinook salmon sampled by WDFW at RM 34.5 in 2001 have not yet been calculated, it is possible that up to 40 percent of the unmarked Chinook salmon captured during this period had originated from one of the hatcheries[5].

[5] This estimate is based on the fact that most Chinook move downstream prior to the release of hatchery fish. Of these, some die, some move to Puget Sound, and some rear in areas tat were sampled.

Catches of unmarked natural and hatchery salmon peaked at 36 fish per set on May 22, four days after the release of 200,000 unmarked CWT hatchery Chinook, then declined steadily to five fish on June 4, before increasing to 23 fish on June 12. Thereafter, catch rates declined sharply to three fish per set during late June through late July. No Chinook salmon were captured on August 6 and 23.

Catch rates of subyearling Chinook salmon at RM 13 were compared with river flow to determine whether greater numbers of fish migrated through the reach during higher flows. In 2001, higher catch rates did tend to occur during days of higher flows (Figure 3-36). This pattern was most apparent on June 12, when a freshet led to a 150 percent increase in flow and the catch rate increased 350 percent over values during the previous week. Regression analysis indicated catch rates were positively correlated with flow during May and June (Figure 3-36). However, this finding is complicated by the fact that both flow and abundance of Chinook salmon in the river declined from May through July.

3.8.2 Hatchery Subyearling Chinook Salmon

Approximately 3.5 million hatchery Chinook salmon were released from May 18 to June 11, 2001 (Tables 3-14 and 3-15). Approximately 70 percent of these fish were released during late May. Additionally, approximately 0.54 million marked Chinook salmon were released above Howard Hanson Dam during early April, of which approximately 19,800 may have moved downstream (see Seiler et al. 2002). Although no hatchery Chinook salmon were captured at RM 13 prior to May 18, catches of hatchery Chinook salmon increased rapidly to an average of 14 fish per set (range: 4.6-20.3 fish) between May 22 and June 12 (Figure 3-35). Catches of hatchery Chinook salmon then declined to an average of 1.5 fish per set in late June, and to 0.2 fish per set in July. No hatchery Chinook salmon were captured on August 6 and 23.

The percentage of unmarked subyearling Chinook salmon among the total number of subyearling Chinook salmon captured at RM 13 declined rapidly following the initial release of hatchery fish on May 18 to approximately 75 percent in late May to 26 percent on June 4 (Figure 3-37). The percentage of unmarked Chinook salmon increased rapidly during late June, after many of the hatchery fish had migrated through the watershed. The percentage of unmarked Chinook salmon equaled or exceeded 90 percent during July.

3.8.3 Yearling Chinook Salmon

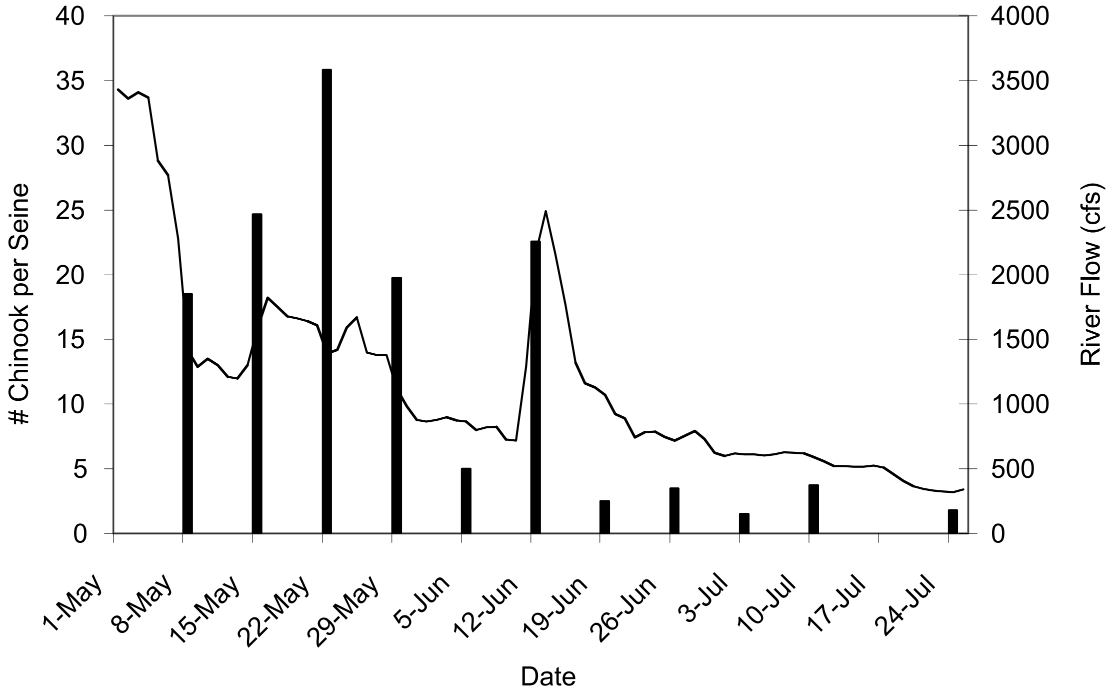
Relatively few yearling Chinook salmon were captured at RM 13 between May 8 and late August 2001 (total catch: 18 natural and 53 hatchery salmon). Most unmarked yearling Chinook salmon were captured on May 15 and May 22 (avg. 1.0 to 2.2 fish per set), and none were captured after June 1.

Table 3-14 Salmon and steelhead releases by the Green River Hatchery complex, 2001. Source: PSMFC, RMIS database.

Species	Age	Location	Release Date	Number released: No CWT + No Clip	Ad+CWT	CWT only	AD only	% bad clip	wt (g)
Coho	yearling	Soos Creek	9-Apr	24,271	34,053	40,388	194,646		26.7
Coho	yearling	Soos Creek	18-Apr	21,096			183,062		26.7
Coho	yearling	Soos Creek	24-Apr	1,018	4,830	5,015	43,337		23.9
Coho	yearling	Soos Creek	24-Apr	4,256	4,916	4,961	35,687		25.2
		Total Yearling Coho		**50,641**	**43,799**	**50,364**	**456,732**		
Coho	subyearling	Hill Creek 9.0051	17-Apr	205,668					0.8
Coho	subyearling	Springbrook Creek	17-Apr	70,329					0.8
Coho	subyearling	9.002	17-Apr	73,875					0.8
		Total Subyearling Coho		**349,872**					
Steelhead	yearling	Green River (Icy Creek)	1-May				199,578		81.0
Chinook	yearling	Green River (Icy Creek)	1-May				241,300		56.7
Chinook	subyearling	Soos Creek	18-May	9,089			558,990		5.7
Chinook	subyearling	Soos Creek	18-May	2,566		202,658			5.9
Chinook	subyearling	Soos Creek	18-May	3,203	194,248		2,758		6.0
Chinook	subyearling	Soos Creek	22-May	10,705			658,374		7.1
Chinook	subyearling	Soos Creek	30-May	11,308			695,444		5.9
Chinook	subyearling	Soos Creek	1-Jun	2,747			168,953		6.1
Chinook	subyearling	Soos Creek	4-Jun	1,767			108,676		5.7
Chinook	subyearling	Soos Creek	4-Jun	3,019			185,681		6.0
Chinook	subyearling	Soos Creek	5-Jun	1,843			113,360		5.7
Chinook	subyearling	Soos Creek	6-Jun	2,731			167,966		5.7
Chinook	subyearling	Soos Creek	6-Jun	1,904			117,072		6.0
Chinook	subyearling	Soos Creek	11-Jun	2,730			167,870		5.7
		Total subyearling chinook		**53,612**	**194,248**	**202,658**	**2,945,144**		

Table 3-15. Salmon and steelhead releases into the Green River watershed by the Muckleshoot Indian Tribe, 2001. Source: PSMFC, RMIS database.

				Number released				
Species	Age	Location	Release Date	No CWT + No Clip	Ad+CWT	CWT only	AD only	wt (g)
Chinook	subyearling	Friday Creek	2-Apr	2,599			27,977	2.2
Chinook	subyearling	Green River	2-Apr	2,687			28,929	2.2
Chinook	subyearling	McCain Creek	2-Apr	3,660			39,396	2.2
Chinook	subyearling	Snow Creek	3-Apr	3,518			37,874	2.2
Chinook	subyearling	Sunday creek	3-Apr	5,392			58,048	2.2
Chinook	subyearling	Smay Creek	4-Apr	5,304			57,096	2.2
Chinook	subyearling	WF Smay Creek	4-Apr	3,536			38,064	2.2
Chinook	subyearling	Gale Creek	5-Apr	9,489			105,327	2.2
Chinook	subyearling	NF Green River	6-Apr	13,472			145,024	2.2
		Total Subyearling Chinook		**49,657**			**537,735**	
Coho	subyearling	Miller Creek	10-Apr	10,000				0.9
Coho	subyearling	Miller Creek	11-Apr	3,800				0.9
Coho	subyearling	Friday Creek	7-May	38,000				1.2
Coho	subyearling	Green River	7-May	28,500				1.2
Coho	subyearling	InTake Creek	7-May	22,800				1.2
Coho	subyearling	Snow Creek	7-May	21,660				1.2
Coho	subyearling	Sunday Creek	7-May	58,900				1.2
Coho	subyearling	Twin Camp Creek	7-May	28,500				1.2
Coho	subyearling	McCain Creek	8-May	47,880				1.2
Coho	subyearling	Smay Creek	8-May	99,180				1.2
Coho	subyearling	Cougar Creek	9-May	1,900				1.2
Coho	subyearling	Gale Creek	9-May	53,200				1.2
Coho	subyearling	NF Green River	9-May	23940				1.2
Coho	subyearling	9.0233	9-May	19,000				1.2
Coho	subyearling	9.0234	9-May	11,400				1.2
Coho	subyearling	Sylvester Creek	9-May	22,800				1.2
		Total Subyearling Coho		**491,460**				
Coho	yearling	Crisp Creek	7-May	4,570	45,582	1,100	143,748	37.2
Chum	subyearling	Crisp Creek	26-Apr	96,540				2.4
Steelhead	yearling	Crisp Creek	9-May				104,000	80.0
Steelhead	subyearling	Duwamish	1-Aug	32,233				1.2
Steelhead	subyearling	Duwamish	1-Aug	5,334				1.4
Steelhead	subyearling	Duwamish	29-Aug	7,420				1.3
		Total Subyearling Steelhead		**44,987**				



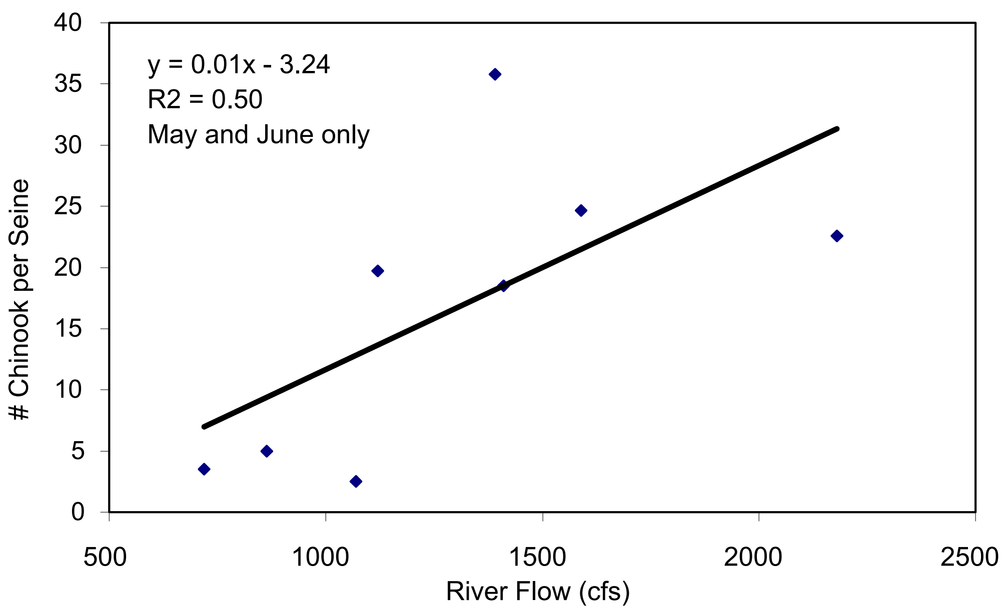


Figure 3-36. Catch per effort of subyearling natural Chinook salmon at RM 13 (vertical axis) in relation to mean daily river flow in the Green River (Auburn gage) 2001.
Lower graph shows the linear regression of catch on flow during May and June 2001.

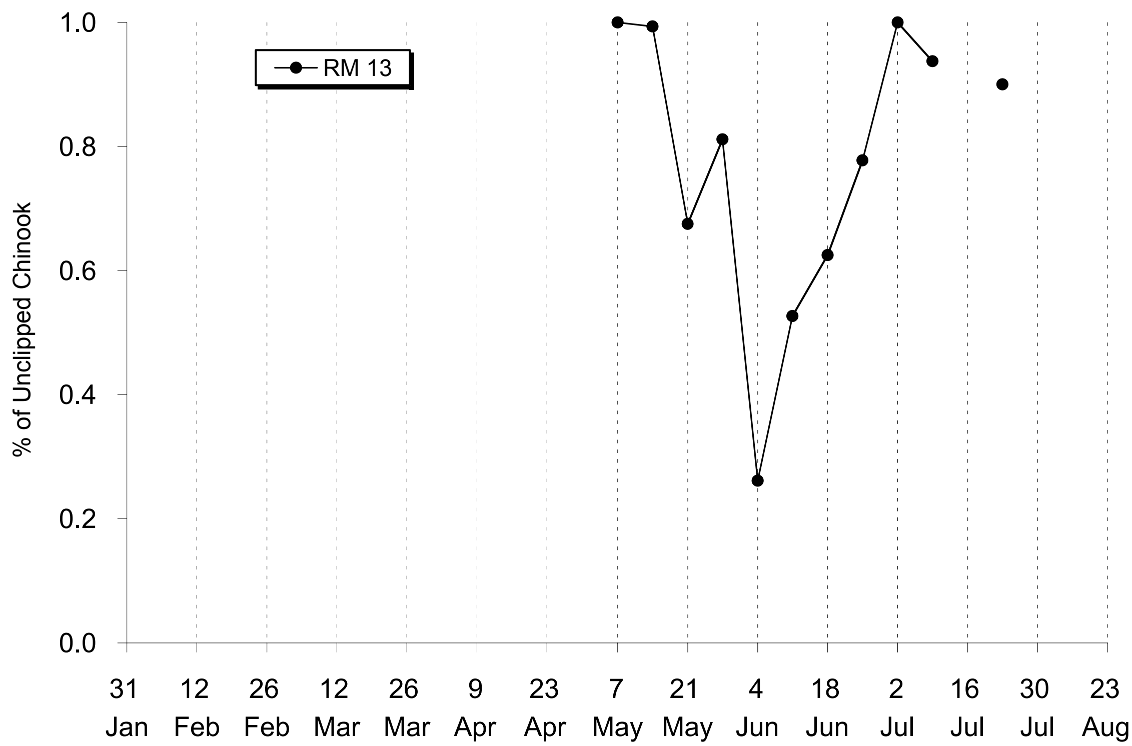


Figure 3-37. Percentage of unclipped subyearling Chinook salmon among total subyearling Chinook salmon captured at RM 13 during 2001. Some hatchery fish contributed to the unclipped salmon catch. Approximately 3.4 million subyearling hatchery Chinook salmon released from May 18 through June 11.

On May 1, approximately 241,300 marked yearling Chinook salmon were released from the Icy Creek holding ponds at RM 48.3. No hatchery yearlings were captured on May 8, but six fish per set were captured on May 15, and 2.2 fish per set were captured on May 22, indicating that some yearling hatchery Chinook salmon had remained in the river for at least three weeks. It is also possible that some of these fish originated from the release of 313,000 marked subyearling Chinook salmon upstream of Howard Hanson Dam in 2000.

3.8.4 Other Salmonids

Other salmonids captured at RM 13 included 237 chum fry, 23 natural coho fry, four hatchery yearling coho, 10 unidentified yearling coho, seven natural steelhead, six hatchery steelhead, and six unidentified trout. These fish were much less abundant than the 1,217 natural subyearling Chinook salmon and the 710 hatchery subyearling Chinook salmon captured at RM 13 during 2001. These catches and those of other species are described by Nelson and Boles (2003).

3.9 YEAR 2001 CHINOOK SALMON SIZE

3.9.1 Natural Subyearling Chinook Salmon

As in 2002 and 2003, the size of natural subyearling Chinook salmon increased little from late January through early April (avg. 40 to 42 mm). This period of low growth likely reflected the presence of newly emerged fry, cold water temperatures, and relatively low prey availability. Thereafter, Chinook salmon size increased rapidly from a mean of 43 mm in early April, to 60 mm in early May, and 87 mm in mid-June (Figure 3-38). This calculated mean size after early May was is probably somewhat overestimated due to the presence of relatively large numbers--possibly up to 50 percent of the catch during this period--of unmarked hatchery Chinook salmon that could not be not distinguished from natural Chinook. Size increased little in late June and July, probably because the few remaining fry in the Middle Green River were relatively small.

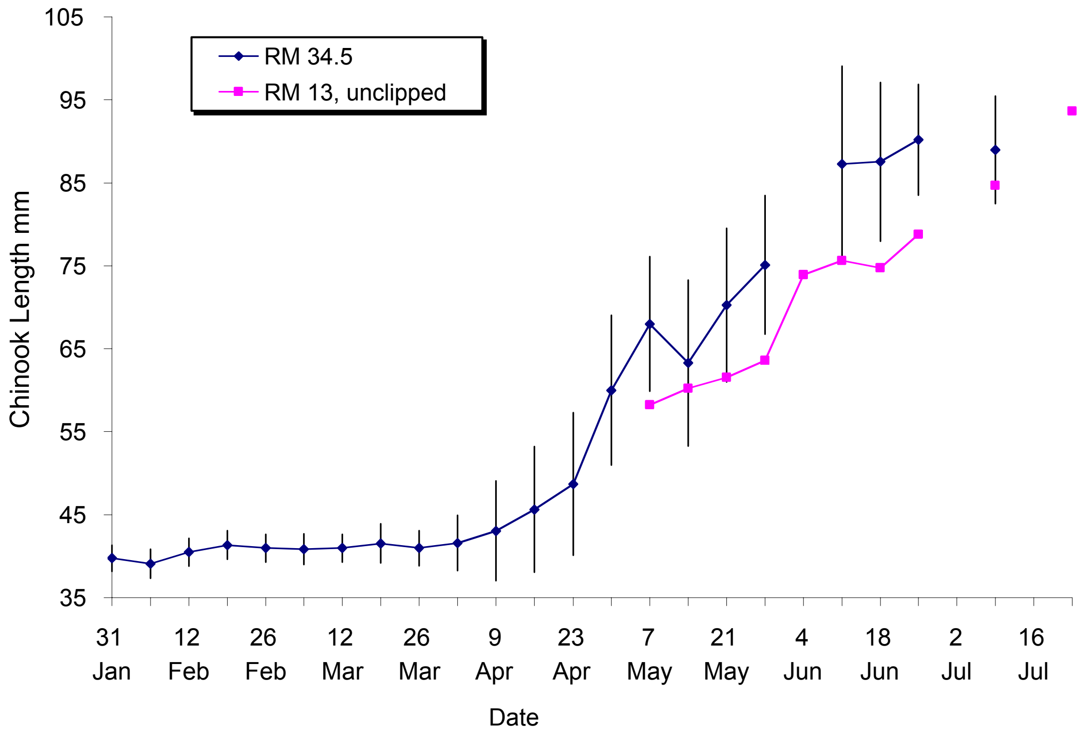


Figure 3-38. Mean length in mm (± 1 SD) of natural subyearling Chinook salmon at RM 34.5 and unmarked salmon at RM 13, 2003.

The mean length of natural and unmarked hatchery subyearling Chinook salmon at RM 13 was consistently smaller than that of fish measured at RM 34.5 during the same week (Figure 3-38), averaging 9.2 mm less. This size differential was unexpected since it was not observed in 2002 and 2003[6], and

[6] In 2003, length of natural Chinook salmon at RM 13 was 3 mm less, on average, than those at RM 18 during week 20 (May 11), but during week 21 (May 18) and week 23 (June 1) length at RM 13 was 3 to 7 mm greater, respectively. Thus, fish at RM 13 did not appear to be biased small in 2003.

because samples at RM 13 included some hatchery Chinook salmon that were larger than natural fish (see below). The smaller size of Chinook salmon captured at RM 13 may reflect: (1) the presence of potentially smaller natural Chinook salmon originating from spawning areas downstream of RM 34.5; and/or (2) extended rearing in the Lower Green River and capture by beach seine of smaller individuals at RM 13 during 2001, possibly in response to lower prevailing water velocities. Although selective mortality of larger individuals (e.g., predation) could also explain the small mean size of Chinook salmon caught at RM 13, selective mortality seems unlikely since most piscivores consume smaller than average prey. Although prey availability and growth within the RM 13 area undoubtedly affected the size of Chinook salmon captured there, it is unlikely that this growth would have led to the observed discrepancy in fish sizes at RM 34.5 vs. RM 13, because this would imply that these fish had reared in this reach for an extended period but grew exceptionally slowly during this time.

3.9.2 Natural versus Hatchery Subyearling Chinook Salmon

During late May, hatchery Chinook salmon were approximately 18 mm longer than natural Chinook, but this difference declined to 5 mm in late June. Overall, length of hatchery Chinook salmon was 9 mm, on average, longer than unmarked fish at RM 13 during late May to late June, 2001 (Figure 3-39). Nevertheless, there was considerable overlap in the range in hatchery and unmarked Chinook salmon lengths.

A histogram of natural Chinook salmon lengths shows that length had a normal distribution during early May prior to the release of hatchery Chinook salmon (Figure 3-40). After the release of hatchery Chinook, the distribution of unmarked fish was positively skewed, reflecting the presence of numerous unmarked hatchery fish. The release of large numbers of unmarked hatchery Chinook salmon led to an overestimation of natural salmon length. Therefore, in 2001, estimates of daily growth were not calculated.

3.9.3 Yearling Chinook Salmon

Histograms of fish length were used to identify yearling Chinook salmon, which were typically considerably longer than subyearling Chinook. Natural Chinook salmon exceeding 95 mm prior to June 1 were typically yearling salmon. Unmarked yearlings averaged 113 ± 8 on May 15, and 126 ± 26 mm on May 22 (range: 100 to 154 mm). The mean length of hatchery yearlings was 118 mm (range: 115 to 190 mm). It is possible that hatchery Chinook salmon released in 2000 contributed to the yearling catch in 2001 (Table 3-16).

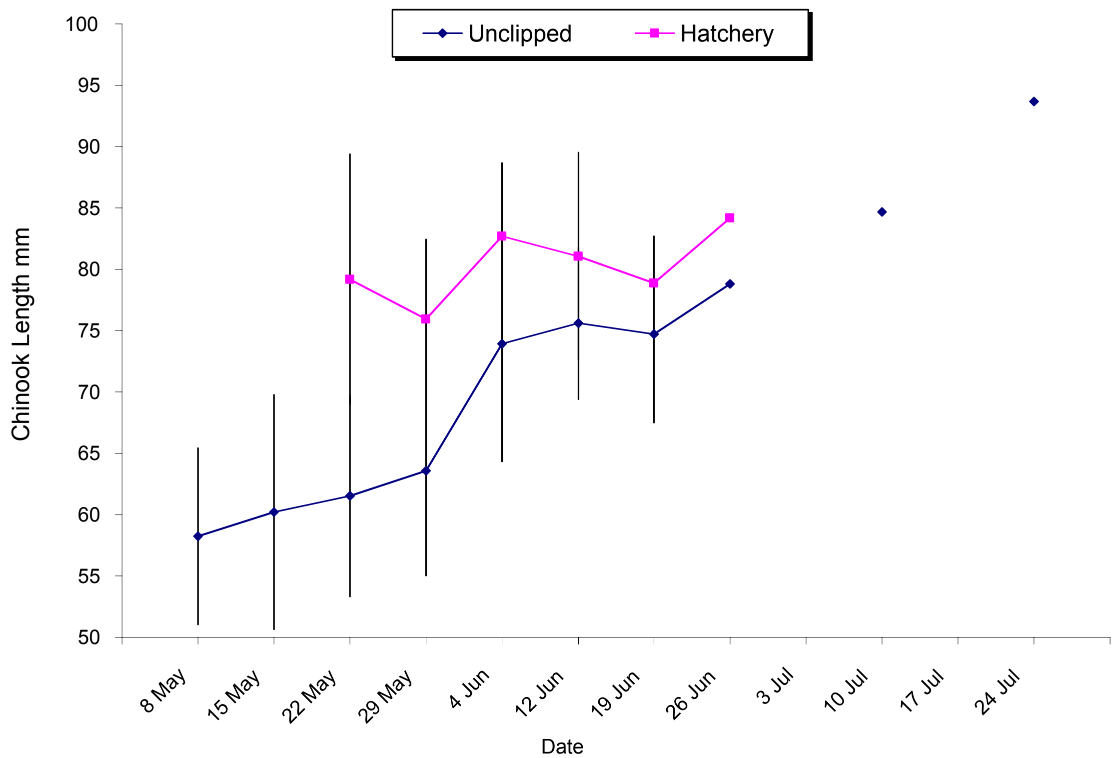


Figure 3-39. Mean length (±1 SD) of unclipped and hatchery subyearling Chinook salmon at RM 13, 2001.
NOTE: After May 15 numerous unclipped hatchery salmon were released and could not be visually separated from natural Chinook salmon. This caused an upward bias in the length of natural Chinook salmon. Values on June 4 were collected over a two-day period at RM 5.5.

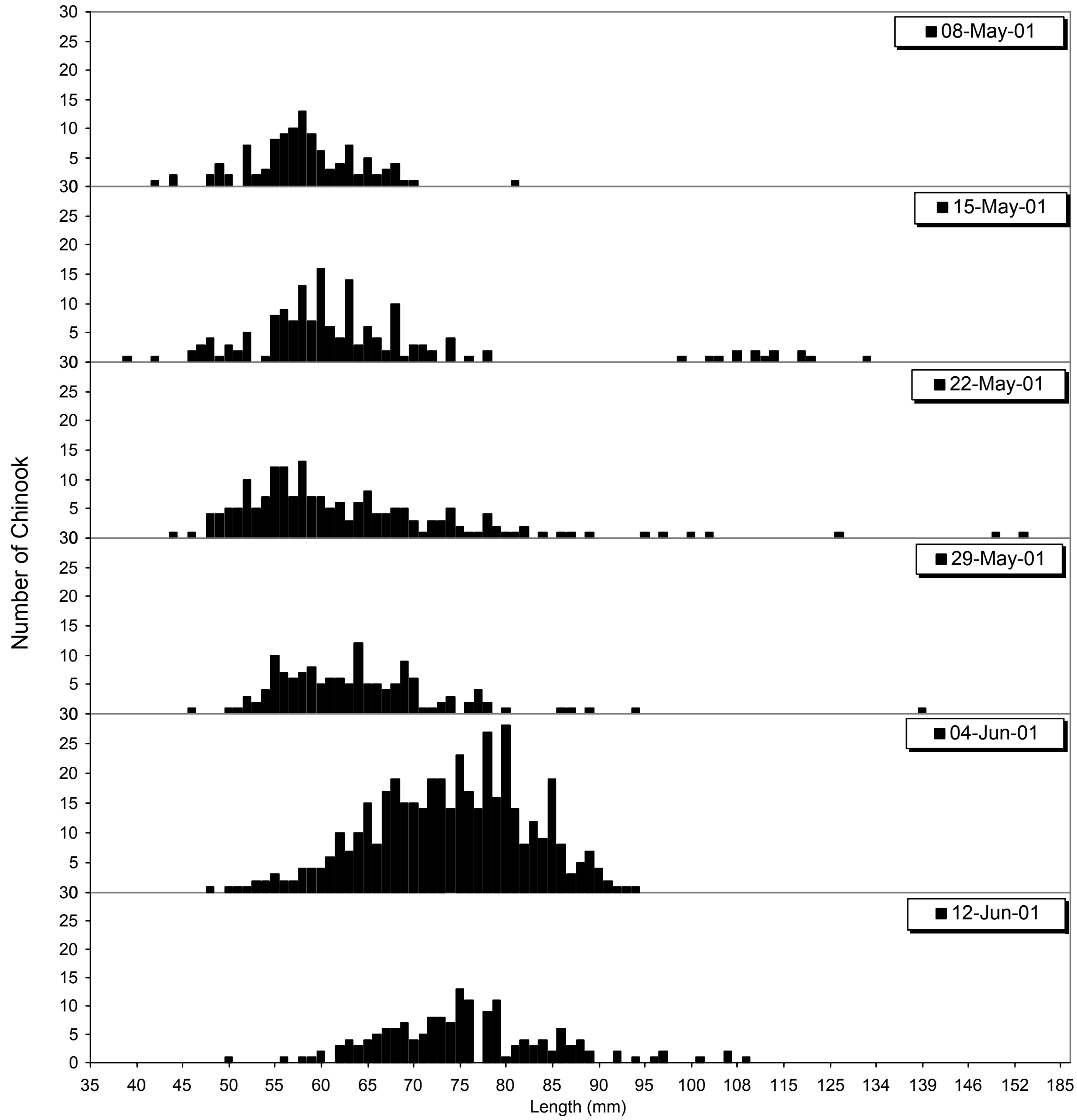


Figure 3-40. Length (mm) histograms of natural subyearling and yearling Chinook salmon sampled at RM 13 during May 8 to June 19, 2001.

Table 3-16. Releases of subyearling salmon into the Green River watershed by the WDFW Green River hatchery Complex and the Muckleshoot Indian Tribe, 2000.
NOTE: Some of these subyearling salmon may have been present in the watershed as yearlings in 2001. Source: PSMFC, RMIS database.

					Number released			%	
Species	Age	Location	Release Date	No CWT + No Clip	Ad+CWT	CWT only	AD only	no clip	wt (g)
Chinook	subyearling	Soos Creek	8-Mar	40,000					1.19
Chinook	subyearling	Soos Creek	13-Mar	374,800					1.73
Chinook	subyearling	Soos Creek	9-May	119,615	193,355	201,589	2,581,854		5.9
	Total Subyearling Chinook			**534,415**	**193,355**	**201,589**	**2,581,854**	**21%**	
Chinook	subyearling	Coal Cr	27-Mar				48,048		2.75
Chinook	subyearling	Cougar Cr	27-Mar				32,560		2.75
Chinook	subyearling	NF Green River	27-Mar				32,560		2.75
Chinook	subyearling	9.0233	27-Mar				60,016		2.75
Chinook	subyearling	Green River	28-Mar				23,760		2.75
Chinook	subyearling	McCain Cr	28-Mar				38,192		2.75
Chinook	subyearling	Smay Cr	28-Mar				78,218		2.75
	Total Subyearling Chinook Above H.H. Dam						**313,354**	**NA**	
Coho	subyearling	Soos Creek	1-Mar	1,000					0.45
Coho	subyearling	Snow Cr	20-Apr	39,925					1.40
Coho	subyearling	Sunday	20-Apr	79,850					1.40
Coho	subyearling	Duwamish	25-Apr	29,850					1.46
Coho	subyearling	Friday Cr	25-Apr	29,850					1.46
Coho	subyearling	Green Canyon Cr	25-Apr	29,850					1.46
Coho	subyearling	McCain Cr	25-Apr	29,850					1.46
Coho	subyearling	9.0233	26-Apr	29,850					1.46
Coho	subyearling	9.0234	26-Apr	29,850					1.46
Coho	subyearling	Smay Cr	26-Apr	59,700					1.46
Coho	subyearling	NF Green River	27-Apr	81,650					1.46
	Total Subyearling Coho Above H.H. Dam			**441,225**				**100%**	

3.10 COMPARISON OF CHINOOK SALMON IN 2001, 2002, 2003

3.10.1 Abundance and Timing

Catch rates at the RM 34.5 screw trap were approximately three times greater in 2001 compared with catches in 2002 and 2003. The large catches in 2001 occurred during exceptionally low winter flows (November through March mean daily flow: 774 cfs), which were 59 percent below the long-term average (1,915 cfs). Winter flows in 2002 were average (1,960 cfs), whereas flows in 2003 (1,490 cfs) were below average but exceptionally variable (range of monthly means: 297 to 2,620 cfs). These catch values do not account for trap efficiency, which may vary with river flow and fish size. Variation in spawning escapement does not explain the high catches in 2001, because the 2000 natural spawning escapement (10,526 fish; mark-recapture method) was considerably lower than the escapements in 2001 (21,402 fish) and 2002 (14,857 fish) (T. Cropp, WDFW, pers. comm.).

Migration timing varied from year-to-year. During 2001 and 2002, approximately 65 percent of the catch at RM 34.5 were relatively small fish (<70 mm) that migrated prior to mid-April. In contrast, approximately 90 percent of the fish migrated prior to mid-April during 2003. Late winter flows in 2003 (avg. max flows from January through March: 7,268 cfs) were high compared with flows in 2001 (1,957 cfs) and 2002 (4,423 cfs), and may have pushed a greater percentage of the smaller fish downstream in 2003, leaving fewer fish in the Middle Green River to migrate at a later date. However, larger numbers of fry were also captured at RM 34.5 during relatively low flow periods in 2003, indicating that some fry may have migrated actively rather than passively. During January and February of 2003, approximately three percent of the fry observed at RM 1.0 near Kellogg Island still had yolk, indicating recent emergence and rapid travel from the spawning gravels in the Middle Green River. Because early migrating fish are much smaller than later migrating fish, and because habitat utilization likely varies with fish size, shifts in migration timing are likely to lead to year-to-year variation in habitat utilization in the lower river and estuary.

These data suggest that high winter flows might force a larger percentage of Chinook salmon juveniles to rear in the lower river, estuary, and Elliott Bay nearshore, but further study is needed to determine the importance of active migration of Chinook fry during late winter and early spring, and the potential effects of flow on migration. Healey (1991) reviewed migration timing of subyearling Chinook salmon in Northwest rivers and concluded that numerous fry migrate downriver, then rear for weeks or months in the estuary before entering marine waters. In the Duwamish River, the remnant functional "estuary" may be limited to the transition zone area between RM 5.5 and RM 6.5. The area downstream of RM 5.5 is now a deeply dredged marine inlet lined by oversteepened, riprap-lined banks and docks. Based on Healey's findings, fish captured downstream from the transition area and in nearby marine waters in Elliott Bay during late winter 2003 may have been transported into these area by high flows.

3.10.2 Fish Length

Mean length of natural subyearling Chinook salmon at RM 34.5 varied from year-to-year. Chinook salmon length was similar from the beginning of February through mid-March. After mid-March, length in 2001 and 2003 increased relative to length in 2002 (Figure 3-41). During April through June, the mean length of subyearling Chinook salmon in sampled at RM 34.5 in 2002 averaged 7.4 mm (11 percent) less than the mean lengths of subyearlings in 2001, and 6.9 mm (10 percent) less than those in 2003.

Between RM 6.5 and 0, the mean length of Chinook salmon were also consistently smaller in 2002 compared with those captured in this reach in 2003. During May through June, the length of subyearling Chinook salmon in 2002 averaged 6.5 mm (8 percent) less than fish in 2003. However, in 2001, the mean lengths of Chinook salmon at RM 13 were 3.8 mm and 10.3 mm shorter than those sampled within this reach during 2002 and 2003, respectively. The relatively small size of fish at RM 13 in 2001 is inconsistent with annual growth observed at RM 34.5 and with growth observed at RM 13 during 2002 and 2003. This inconsistency is likely related to the unusually small size of fish observed at RM 13 compared with those sampled at RM 34.5 during 2001 (see comment above), possibly reflecting a relative abundance of late emerging fish from spawning areas downstream of RM 34.5 and/or extended rearing of smaller fish in the lower velocities that prevailed in 2001. This finding did not appear to be an artifact of gear type, because it was not observed in 2003 (See Appendix E for statistical analysis of effect of gear type on Chinook salmon length).

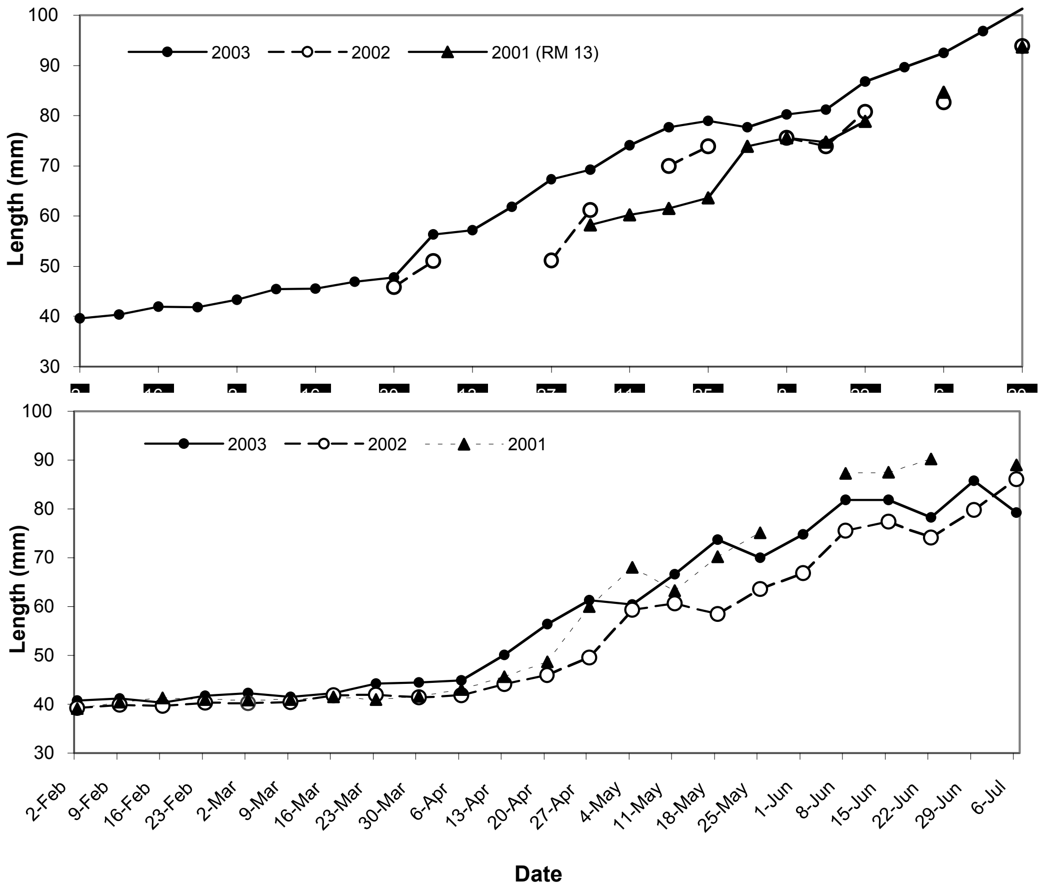


Figure 3-41. Comparison of natural subyearling Chinook salmon mean length (mm) at RM 0-6.5 (upper graph) and RM 34.5 (lower graph) during 2001, 2002 and 2003.
In 2001, fish length data were from RM 13.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

This chapter contains conclusions and recommendations arising from the JSSS. The conclusions are divided into four sections: (1) natural Chinook salmon timing and abundance; (2) size and growth of natural and hatchery Chinook; (3) river flow and natural Chinook salmon response; and (4) coded wire tag information. Recommendations are divided into those that support salmon habitat planning and future studies.

4.1 CONCLUSIONS

4.1.1 Natural Chinook Salmon Timing and Abundance

This study confirmed the existence of four natural juvenile Chinook salmon life history trajectories as described in the Introduction:

1. fry (enter estuary at about 40 mm in the late winter);
2. fry/fingerlings (enter estuary from 45-70 mm in early spring);
3. fingerling (enter at 70 mm or more in spring); and
4. yearlings (enter estuary at 140 – 175 mm in spring).

Most of the evidence for these trajectories comes from the following timing and abundance information.

<u>4.1.1.1 Subyearlings</u>

During three successive years of sampling from 2001 to 2003, natural subyearling Chinook salmon were found rearing and migrating in the Green/Duwamish River between RM 34.5 and Elliott Bay from the onset of sampling in late January to early September.

- **Subyearling Chinook salmon migrated past RM 34.5 beginning in January, and showed two peaks in abundance, which varied annually in relative magnitude.** The first peak occurred from late February to early March, and the second from mid-May to mid-June. The early peak represents migration of fry (about 40-mm fork length), and the later peak was composed of fingerlings (about 75 mm). In 2003, the fingerling migration peak was less pronounced than the prior two years of sampling. The relative differences in fry vs. fingerling abundance may result from annual variations in flow conditions, as it appears that high flows from January to March may have flushed juveniles from the Middle Green River prematurely in 2003. In all three years, few fish were captured at RM 34.5 after mid-July; thus juvenile migration from upstream areas appears to be nearly complete by then.
- **Chinook salmon juveniles from the Middle Green River appeared to move quickly through the free flowing river and tidally influenced freshwater reaches (from RM 34.5 to RM 6.5) in 2002 and 2003.** Catches or fry and fingerlings at RMs 18, 13, and 7 coincided with the two peaks at RM 34.5. Most Chinook fry marked at Soos Creek were captured at RMs 13 and 7 within 48 hours, indicating that most fry migrated rapidly through the Lower Green River in 2003. In 2001, sampling at RM 13 did not begin until after fry migration was complete so timing of fry from RM 34.5 could not be compared. In 2001, catches of fingerlings at RM 13 peaked at approximately the same time as at RM 34.5, suggesting a rapid fingerling migration through the Lower Green River. Low flow

conditions in the Lower Green River curtailed sampling efforts in the free-flowing river study reach during August of each year, but catches had become consistently low in the downstream study reaches by then, indicating that migration was complete.

- **By far, the most abundant and consistent catches of subyearling Chinook--both fry and fingerlings--occurred in the Duwamish River estuary transition zone at the Trimaran site at RM 6.5 and at the Turning Basin at RM 5.5.** Chinook salmon were captured starting at the beginning of the sampling season in late January in 2002 and 2003[1]. The highest relative concentrations of fry were observed in late February 2003, probably due in part to high flows, which rapidly flushed fry downstream through the Middle and Lower Green River. Catches of fry/fingerlings were relatively high in April of 2003 (Figure 3-12), at a time when catches were relatively low at RM 34.5, suggesting that fry/fingerlings inhabited the Lower Green River for a while before moving into the transition zone. Juvenile Chinook salmon were captured in the transition zone until late June and early July, when catches sharply declined. Very few natural Chinook salmon were captured in the transition zone from early July through early September, indicating most natural Chinook salmon had moved through the transition zone and into the lower estuary and nearshore marine areas by early July.
- **Chinook salmon catches in the lower Duwamish River estuary exhibited a later timing pattern compared with those in the transition zone.** Chinook salmon were captured consistently through late August in the lower Duwamish estuary. Except for a brief period in early February 2003, during a period of high river flows when fry were likely washed into the area, the concentration of fish in the lower estuary never rivaled that in the transition zone. Chinook salmon catches in the estuary were usually less than 25 percent of those in the transition zone. This could indicate a juvenile preference for the transition zone in the estuary and rapid seaward migration once it is vacated.
- **Catch rates in the nearshore areas of Elliott Bay were considerably smaller than catches in the transition zone and the estuary.** In 2003, Chinook fry appeared in Elliott Bay for a short period from late January to early February. High river flows during this time were the probable cause for the early appearance of these fry in nearshore marine habitats. In 2002 and 2003, Chinook salmon juveniles were also captured at the Elliott Bay sampling sites in mid-May, and catches peaked from late June to early July, coinciding with declining numbers of fish in the Duwamish estuary. Juvenile Chinook salmon continued to be captured in small numbers at these nearshore locations through early September.

4.1.1.2 Yearlings

- **A small but persistent migration of natural Chinook salmon yearlings occurred during all three years of the study.** Hatchery supplementation and the inefficiencies associated with mass marking thousands of fry may confound the true origin of unmarked (natural) Chinook salmon captured. Many of the yearlings apparently are not the result of poor marks from the yearling rearing facility at Icy Creek since approximately half of the natural 2002 and 2003 yearlings were captured in late March and late April, prior to release of hatchery yearlings. If unmarked hatchery fish are adding to the natural yearling catch, a more likely source is from fish planted into the Upper Green River Subwatershed. About five hundred thousand Chinook fry are released annually (Tables 3-4, 3-13, 3-15, and 3-16) upstream of Howard Hanson Dam and passage delays at the dam or colder water conditions may extend their river rearing period.

Where natural yearlings are rearing during fall and winter is somewhat of a mystery, although there have been reports of yearling-size Chinook salmon in Mill Creek (Jones and Stokes, 1989). It is also possible

[1] In 2001, sampling was conducted only at RM 13 beginning in May.

that some yearlings, the majority of which were captured in the Duwamish transition area and estuary, could have migrated into the Duwamish River from other river systems in the Puget Sound. Some of the Chinook salmon that were large enough to be two-year-old-fish may be part of a resident Puget Sound population ("blackmouth") entering the Duwamish for opportunistic feeding.

4.1.2 Size and Growth of Natural and Hatchery Chinook

- **Subyearling Chinook salmon reared at the WDFW Green River hatchery at Soos Creek were consistently larger, on average, than natural Chinook salmon through the entire sampling season at all sampling locations throughout the study.** The size at age of hatchery fish is likely greater due to consistently abundant food supply and the low energy environment prior to release. This size differential may imply hatchery Chinook salmon are initially more tolerant of low prey availability, due to fat reserves, and they may have a competitive advantage over their natural conspecifics.
- **In May and June 2001, natural Chinook salmon average fork lengths were found to be consistently smaller at RM 13 than those captured during the same week over this period at RM 34.5.** This was not the case for catches in 2002 and 2003, when sizes of Chinook salmon sampled at the downstream locations were consistently greater than those of fish captured at RM 34.5. This suggests that a different, smaller, group of Chinook salmon were rearing downstream of RM 34.5 in the Lower Green River. The smaller size could possibly be due to later emergence timing of fry produced downstream of the trap at RM 34.5. Alternatively, the low river flow and velocity in 2001 may have allowed for rearing of smaller fry in the channelized lower river where there is otherwise little refuge from moderately high flows.
- **The release of over three million hatchery Chinook, coinciding with a time of high natural Chinook salmon abundance in the Duwamish transition zone, resulted in substantially reduced growth of natural Chinook.** In 2003, a strong correlation was seen between the two to three-week residency of hatchery fish in the transition zone, and the abrupt decrease in natural Chinook salmon growth, from 0.54 mm/day to 0.13 mm/day during the same period. Chinook salmon growth rates in the transition zone resumed to near pre-hatchery release levels, averaging 0.44 mm/day, once the hatchery fish moved into Elliott Bay. This reduction in relative growth during high salmon abundance in the transition zone suggests that there may be capacity limitations related to inadequate quantity or quality of transition zone habitat and associated prey production. In addition to the reduction in growth, the natural fish appear to have been displaced from the transition zone during the three-week hatchery fish occupation.

4.1.3 River Flow and Natural Chinook Salmon Response

Information gathered during the course of this study suggests that river flow may play an important role in shaping the natural juvenile Chinook salmon life history trajectory expressed in a given year. Therefore, interannual variations in river discharge may lead to annual differences juvenile Chinook salmon survival and eventually the numbers of natural adults returning to spawn.

- **Low winter and early spring flows observed in 2001 may have lead to conditions that resulted in the production of more natural fingerlings than in the following two years.** This implies that habitats in the Middle and Lower Green River are more conducive for juvenile rearing during low flows, which appear to result in more upstream freshwater rearing of juveniles. The Chinook salmon size differential observed in 2001 (see above) at RM 13 could also imply that smaller juveniles are able to rear for an extended period in the Lower Green during low flow years. This in turn could mean that increasing the quality and quantity of low velocity habitat areas in the Lower Green River could increase the percentage of outmigrants that exhibit the fingerling trajectory, (i.e., fingerling-size) fish prior to entry to the transition zone. In higher flow years, these fish may be flushed involuntarily downstream to the first available low velocity habitat area, which is the transition zone. These high flow velocities result in juveniles arriving as fry rather than as larger-bodied fingerlings. This hypothesis is consistent with observations in 2003 of juvenile Chinook salmon occupying backwater eddies formed by shoreline woody debris near RM 13, and pools during low to moderate late winter flows, followed by the disappearance of fish from these areas following freshets.

- **High flows in late winter 2003 (January to early February) appeared to flush fry rapidly downstream into the estuary.** The appearance of yolk-sac fry at RM 1.0 after high flow events suggests that these fish were prematurely carried downstream. However, it should also be noted that fry migration past RM 34.5 on the mainstem and past RM 0.9 on Soos Creek also spiked during steady to declining stream hydrographs in early March of 2003. This shows that natural fry disperse downriver even when high flows are not present. In other watersheds, dispersal of fry has been thought to be a mechanism that minimizes intraspecific competition, although it is also accepted that high flows limit suitable low velocity habitats and carry fry down river (Healey 1991).
- **The high flows that occurred in late 2001 may have scoured eggs that would otherwise have produced fry for the 2002 migration, and lowered the number of fry seen in the transition zone.** Spawner escapements and flows between late January and late February were similar for the 2002 and 2003 study, and thus the significantly lower abundance of Chinook salmon fry in the transition zone in 2002 cannot be explained solely by variations in these factors. Numbers of fry captured at the RM 34.5 trap were approximately 26% less in 2002 than 2003 and 80-90% less in the transition zone. It is interesting to note that a series of high flow events occurred from November through December in 2001, but not in 2002.

4.1.4 Coded Wire Tag Information

- **Based on CWT analysis in 2002 and 2003, most Green River hatchery Chinook salmon appeared to move through the lower river and estuary in approximately two weeks and leave the marine nearshore of Elliott Bay by mid-June.** Few of the Green River hatchery CWT fish remained in the study area after mid-June. Instead, tagged fish from other Puget Sound watersheds began to appear around this time. Assuming natural fish behavior is similar, this finding demonstrates the importance of the Puget Sound marine nearshore as a whole in providing juvenile rearing habitat for natural Green River Chinook salmon, as well as for Chinook salmon stocks from other south and central Puget Sound watersheds.
- **In 2003, WDFW reported releasing equal numbers of CWT Chinook salmon with and without adipose fins (ad-clipped) but the JSSS found about twice as many CWT fish with adipose fins intact than missing.** This discrepancy remained constant over time and at various collection locations. It appears that either the adipose-clipped fish suffered higher mortality than the unclipped CWT fish, or they were incorrectly enumerated. In either case, this apparent discrepancy could seriously affect the validity of WDFW adult harvest and survival rate calculations, if not accounted for. This discrepancy was not observed in other years, or for other CWT stocks.

4.2 RECOMMENDATIONS

4.2.1 WRIA 9 Habitat Plan

- **Restoring habitat within the Duwamish estuary transition zone is a high priority.** High densities of juvenile Chinook salmon concentrate there during most of the outmigration season for acclimating to salt water, feeding, and avoiding predators. Juvenile salmon of all species seem to prefer this area because it is the first brackish water, shallow, and low velocity habitat encountered. Catch rates in shallow areas surrounding Kellogg Island, a remnant of the pristine estuary, were much smaller, possibly suggesting that most fish are likely migrating rather than searching for rearing habitat in this area. These observations suggest that the estuarine habitat that provides for extended rearing has been reduced to a very small area around and near RM 5.5-7. The capacity of this habitat to support large numbers of juvenile salmon, including hatchery fish is limited. Evidence for capacity limitation is shown by the apparent competition between hatchery and naturally produced Chinook, leading to reduced growth rates of both natural and hatchery Chinook salmon.

- **Long-term solutions should focus on projects to expand the existing acreage of mudflat and vegetated salt marsh habitat within the transition zone.** Habitat along the Duwamish shore downstream of the transition zone may also be expanded, but existing data suggest fewer fish would utilize these habitats, possibly because it is presently disconnected from the transition zone. More fish may utilize downstream areas for a longer period if suitable habitats were connected. Restoration of salt marsh and mudflat habitats will be necessary to support recovery of Green/Duwamish Chinook salmon stocks, although such projects will be expensive and require considerable planning and time for implementation.
- **Management actions should be undertaken immediately in the estuary that increases available mudflat.** Some of the quickest and least costly actions to gain estuary habitat for rearing Chinook salmon will be found in making the most of what is currently available. Examples of beneficial actions that are relatively inexpensive and quick to implement include: removal of illegal fill and sunken debris, reducing the dredging of mudflat and marsh habitats, and careful placement of barges to avoid shading and grounding of vessels on intertidal habitats.
- **Hatchery practices appear to have deleterious impacts on the growth of natural juvenile Chinook salmon in the transition zone, therefore hatchery production and planting strategies should be critically evaluated and managed to avoid impacting natural Chinook salmon.** Competition between hatchery and natural Chinook salmon is a potentially important factor affecting juvenile salmon survival. Further research on this topic is recommended because only one year of detailed data was collected and because the implications of competition are important to tribal fishermen and others that depend on hatchery salmon.
- **Proper management of river flows is instrumental for natural Chinook salmon survival.** The challenge will be to manage flows within the confines of a highly modified river channel to avoid floods, redd scour and premature flushing of sac fry to the estuary, while promoting natural habitat forming processes associated with episodic high flows in the Middle Green River. Additionally, flows favorable to one salmon species may not be favorable to others.
- **Restoration efforts in the Middle and Lower Green River should attempt to increase areas that allow fish to avoid being swept prematurely to the estuary during high flows.** Creating additional areas of low velocity during high flows (i.e., side or backwater channels) could help to hold the Chinook salmon in the river for additional rearing and growth prior to entering the crowded transition zone and increase survival.
- **WRIA planning entities should integrate their resources to restore essential marine nearshore habitat in a strategic fashion.** The dispersal of Green River juvenile Chinook salmon from the Elliott Bay study area, and their replacement by Chinook salmon from other watersheds beginning in mid-June suggests that Green River Chinook salmon rapidly migrate along the nearshore areas of Puget Sound. This finding contravenes the neatly drawn boundaries of WRIA habitat planning efforts, and underscores the importance of managing marine nearshore habitats on a broader, Puget Sound-wide scale. Green River Chinook salmon readily seek out and occupy suitable marine nearshore wherever they can find it, and can quickly cross-jurisdictional boundaries. This study

suggests the possibility that some of the most beneficial locations for protecting and restoring marine nearshore habitats in order to rebuild the Green River Chinook salmon population may be widespread including areas outside of WRIA 9.

- **Future studies at scales comparable to that of this study will be needed to track the effects of WRIA 9 recovery actions over time.** As one of the first studies to directly evaluate characteristics of natural Chinook salmon (i.e., as opposed to unmarked hatchery salmon), this study provides a foundation for characterizing changes in Chinook salmon growth, behavior, and relative abundance. Similar future studies can gauge Chinook salmon response as the habitat changes due to habitat plan implementation, adaptive management, and other factors.

4.2.2 Recommendations for Future Study

- **Define the upstream and downstream boundaries of the current transition zone.** In 2002 and 2003, high concentrations of Chinook salmon were found at the RM 6.5 and 5.5 sampling sites, but not at the next sites upstream (RM 13), or downstream (RM 1). The physical limits of the transition zone probably extend beyond the current definition of this area, and better defining the exact boundaries and the physical, chemical and biological characteristics would help direct future restoration and enhancement efforts, and protect the salmon that currently depend on it for acclimation to marine conditions.
- **Link juvenile life-history trajectories and the habitats they use to their contribution to adult returns.** Currently, otolith and scale studies are the best methods for tracking relationships between habitat utilization and flow parameters and their effects on juvenile to adult survival. Thus, otolith and scale collection should continue on a yearly basis to help track annual variability in these factors.
- **Estimate the duration of Chinook fry residence in the Duwamish transition zone and estuary more precisely to assess the relationship between estuarine habitat utilization and fish survival.** This could be tracked by studying fish otoliths, and/or mark-recapture studies using dye, fin clips or tags in order to estimate the duration of transition zone and estuary use.
- **Collect additional information to verify the existence, behavior, and patterns of habitat use of natural yearling Chinook salmon.** These yearlings could prove to be an important component in securing the genetic variability, life history diversity, as well as overall viability of the Green River Chinook salmon stock.
- **Identify the habitat locations in the Lower Green River that potentially play an important role in Chinook salmon survival under various flow conditions**. The locations of suitable rearing habitat between RM 34.5 and 13, where juvenile salmonids concentrate (i.e., rearing core areas)–at least during moderate flow years–are not known at present. Identifying these areas, if they exist, would greatly assist in protection and restoration efforts. Exploration of additional fish monitoring sites using snorkel surveys, hydroacoustics, or other suitable fish observation methods will help map and protect such core rearing habitat, as well as inform efforts to restore habitat in the Lower Green River.
- **Carry out and support studies that focus on managing river flows for fish survival and habitat recovery.** Flows appear to be an important factor in shaping annual behavior patterns of juvenile Chinook. Hydraulic analysis should be coupled with analysis of flows in order to determine whether certain structural attributes of the Lower Green River channel can be modified to provide surrogate low velocity conditions within constraints imposed by flood hazard reduction mandates.
- **Future studies examining salmonid outmigration in the Lower Green River should use a screw trap to maximize information.** Seining in the Lower River was not a completely reliable method for monitoring fish habitat utilization because the only feasible seining location in the lower ten

miles of the Lower Green River was at RM 13. Moreover, the river seine method was not effective when flows exceeded 2,500 cfs due to the beach becoming inundated and when flows were less than 300 cfs, because the river was not navigable under low flows. When placed at RM 18, the screw trap proved to be a much more effective method to monitor Chinook salmon outmigration in the Lower Green river. The trap sampled fish nearly continuously during a wide range of discharges, stage levels, and velocities. The trap was able to capture more salmonids over a greater range of sizes than the river seine. Investigators contemplating conducting future Green/Duwamish River juvenile Chinook salmon production studies should consider the use of a screw trap at this location in the Lower Green River.

- **Continue monitoring juvenile Chinook salmon outmigrants on an annual basis.** Due to interannual variability shown by this study, and a number of factors that affect juvenile Chinook salmon growth, behavior and habitat utilization, annual monitoring is recommended. With the additional data, patterns of behavior can be discerned and more definitively related to changing physical parameters such as flow, temperature, and habitat availability. This is especially true when evaluating findings with important economic and management implications such as the impact of hatchery Chinook salmon upon natural Chinook salmon growth in the transition zone and estuary.
- **When using fork length measurements to assess growth of salmon, it is recommended that sampling should occur at least on a weekly basis to account for rapid growth rate changes in response to competition and other factors.**

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APPENDIX A

PRIOR STUDIES RELEVANT TO JUVENILE SALMON SURVIVAL ON THE GREEN/DUWAMISH RIVER

Table A-1. Prior Studies Relevant to Juvenile Salmon Survival on the Green/Duwamish River

Author, Report	River Location	Purpose	Method	Capture Peaks	Relevant Results
Heg 1952. Puget Sound Investigations July 1952 to November 1952. WDF Progress Report.	Lower and Middle Green	Estimate survival difference between Green River Hatchery juvenile chinook released in the estuary vs. those released in freshwater.	Marked two batches of 170,000 hatchery fingerlings using ventral fin clips and released them from late May to early June at Soos Creek and in the Duwamish River at RM 6. Beach seining took place from May through August to recover the marked fish at RM 6 and about RM 5. Fish were sampled for stomach contents.	Chinook – mid to late May	It was estimated that about 51% of the hatchery fish released at Soos Creek would be expected to reach RM 6. Most of the chinook released from Soos Creek arrived at RM 6 by June 12, indicating migration took up to two weeks. Stomach content analysis indicated that chinook migrated between fresh and saline strata in the Duwamish River.
Bostick 1955. Duwamish River Seining Studies, WDF Puget Sound Stream Studies.	Duwamish	To determine the distribution pattern and outmigration timing of juvenile chinook, coho, and chum salmon.	Seine and mark/recapture study from 4/8/55 to 7/20/55.	Chinook – late May to early June Coho – early May Chum – early May	Marked chinook were recaptured up to six weeks after marking. Coho and chum appear to have moved out quickly.
Dunstan et al. 1955. Green River Downstream Migration, WDF Puget Sound Stream Studies.	Middle Green, upstream of Soos and Newaukum creeks	Collect information concerning downstream migration of chum, coho, and chinook salmon.	Two mainstem fyke net rafts fished from 2/18 to 5/20/55.	Chinook – 2/18 to 19 & 4/7, 4/17 Chum – 3/20 to 4/3 Coho 1+ – late April	Chinook, coho and chum juveniles were all captured in February. Gear was deemed to be inefficient due to debris fouling and high mortality when flows exceed 3 fps.
Matsuda et al. 1968. Fishes of the Green Duwamish River, Water Quality Series No. 4, Municipality of Metropolitan Seattle	Duwamish River, from RM 0 to RM 13.0.	Species composition and use of fish in Duwamish River.	Seining on a weekly basis at various locations from 1964 through 1966.	Chinook – late May to early June	Found 30 species present: Pacific herring, chinook, coho, surf smelt, shiner perch, staghorn sculpin, and starry flounder were the predominant species captured in shallow water.

Author, Report	River Location	Purpose	Method	Capture Peaks	Relevant Results
Wetherall 1971. Estimation of Survival Rates for Chinook Salmon During Their Downstream Migration in the Green River, WA. Ph.D. Dissertation, University of Washington	Lower Green River, Duwamish River, Elliott Bay	Estimate downstream migration survival rates for seven experimental cohorts of hatchery chinook using two mark and recapture methods.	Used Jackson method and author's method to study outmigrant travel time by marking and releasing over 400,000 Soos Creek hatchery chinook per year in 1966, 1967, and 1969. Fish were marked using fluorescent pigment applied with a spray gun. Fish were recaptured at RM 13 using beach seine and by using tow nets in the Duwamish River (between RM 5 and 0), and Elliot Bay. Recapture methods were undertaken from mid-May to mid-June.	Fish were released in early May, captures began about a week later, then peaked from mid-May to early June; recapture attempts ceased by mid-June.	Hatchery fish released at Soos Creek were recaptured at RM 13 from 1 to 19 days later, with most being captured from 3 to 7 days after release. Fish released on May 18 at RM 13 were captured in the estuary 5 days later. Hazard rate, defined as an instantaneous death rate, for hatchery fish moving from hatchery to estuary was estimated to be 0.05 per day. Hazard rates were expected to be highly variable but appeared to decrease when fish were in good health and river flows were high. Up to 1.5% of the fish bore lamprey wounds.
Weitkamp 1980. Terminal 107 Fisheries Study, Port of Seattle.	Duwamish River, near Kellogg Island at about RM 2.0	Study fish use of shallow water habitat near Kellogg Island.	Beach seines, purse seines, and gill nets were used from 10/77 through 8/78 at nine locations. Fish were counted, measured, and identified. Daytime seine sampling occurred at varying monthly frequencies from October through August. Effort increased during the spring to maximize salmonid catches. Day and night (1/4-inch mesh) gill net sets were conducted in January, April, June, and August. All fish captured were identified, counted, and measured.	Chinook – mid-May Chum – mid April, late May and mid-June Coho – late April to mid May	Abundant numbers of herring, chum, chinook, coho, steelhead, surf smelt, shiner perch, snake stickleback, staghorn sculpin, and starry flounder were captured. Chinook appeared to reside for two weeks in the Duwamish before outmigrating to the Puget Sound. Coho smolts may have preyed upon chum. Appeared that hatchery chinook released on 5/4/78 appeared to reach the sampling site in 15 to 19 days. Chinook residing in June and July appeared to favor the deeper main channel.

Author, Report	River Location	Purpose	Method	Capture Peaks	Relevant Results
Meyer 1981. Distribution and Food Habits of Juvenile Salmonids in the Duwamish Estuary, USFWS	Duwamish	Examine food habits and distribution of juvenile salmonids and distribution of their prey.	Beach and purse seining from April to July 1980.	Chinook – early May through June Chum – late April and mid-May Coho – early May and early June	Chum were oriented with the shoreline, whereas coho, chinook, and steelhead used areas near the shoreline and the deeper portions of the channel. Chinook tended to move inshore at night and offshore with increasing size. Purse seining was effective for capturing chinook. Mean lengths of chinook and coho caught in purse seine were greater than those caught in beach seine. Catches were greater at night for chinook and steelhead.
Weitkamp and Campbell 1980, Weitkamp and Schadt 1982. 1980 Juvenile Salmonid Study, report to Port of Seattle by Parametrix, Inc.	Duwamish River, select locations from mouth to about RM 5.0	Describe behavior (timing, duration, habitat-specific presence, food) of juvenile salmonids migrating along shorelines of the lower Duwamish Waterway and Elliott Bay.	Beach seine, purse seine, trap, trawl, direct observation, dye mark and recapture, stomach contents analysis from March 27 to late August 1980.	Chinook – mid May to early June Chum – early April and early May Coho – end of April to early May	Most of the chinook which were marked in the Duwamish River and recovered in the Duwamish River and Elliott Bay were recaptured about two weeks later. From the mark recapture study it appeared that fish present in June and July are new fish migrating into the Duwamish River rather than remnants of the group present during the peak of the run. More chinook were captured using traps than by other methods.
Warner and Fritz 1995. The Distribution and Growth of Green River Chinook Salmon and Chum Salmon Outmigrants in the Duwamish Estuary as a Function of Water Quality and Substrate, Muckleshoot Indian Tribe Report.	Duwamish River, from about RM 2 to RM 9.	Determine species composition and timing of all fish use of the estuary. Examine spatial distribution and growth of salmonids, characterize, and determine environmental parameters that influence salmonid distribution.	Seined at 9 locations weekly or biweekly from February to September 1994. Fish were identified, counted, measured, and examined for marks.	Chinook – mid- to late May Chum – late March, mid-April (highest), and May Coho – May	Highest densities of chinook were captured at about RM 6.5. Chinook appeared not to move downstream linearly, but occupied the entire estuary until outmigration. Chinook captured during May peak appeared to reside only about 2 weeks in the estuary.
Priest 2001. King County unpublished report.	Middle Green, from RM 33.5 to RM 44.9	Field review of salmon behavior/stranding potential during reservoir draw-down.	Visual observations made at five side channel locations on May 7, 2001.	Not Applicable	Juvenile chinook and coho found using side channels became stranded during rapid reservoir drawdown.

Author, Report	River Location	Purpose	Method	Capture Peaks	Relevant Results
Jeanes and Hilgert 2001. Juvenile Salmonid Use of Lateral Stream Habitats in the Middle Green River, Washington 2000 Data Report.	Middle Green, from RM 60.0 to RM 33.8.	Monitor emergence, measure growth, determine abundance, and identify species distribution of juvenile salmon. Information to be used to for flow management planning.	Electro-fishing, snorkeling, visual inspection from February through July from 1998 to 2000.	Chinook – March (no 2nd peak) Coho – May Chum – April Rainbow – July	Chinook fry captured from onset of sampling (2/10/99). Chinook used mainstem margins and gravel bedded scour pools. Most chinook captured were about 50 mm-fork length. Two yearling chinook were captured.
Seiler et al. 2002. 2000 Green River Juvenile Salmonid Production Evaluation, WDFW.	Middle Green River, at RM 34.5 and Soos Creek, about RM 1.0.	Estimate and monitor the production of chinook and coho salmon and steelhead and cutthroat trout.	Capture fish continuously from February 10 to July 13 2000 using screw traps located at RM 34.5 on the Green River and at RM 0.5 on Soos Creek. Fish were identified, counted, and measured.	Green River: Chinook – bimodal outmigration: late February to mid-March and early May to early June Chum – mid April Coho 1+ – mid May Soos Creek: Chinook – late February	This study is the first conclusive evidence of the bimodal outmigration of naturally produced juvenile chinook, first the 40 mm "fry" and then the 70mm "fingerlings". Green River: Based on capture of 12,711 0+ chinook, the estimated total migration past screw trap was 546,349. Soos Creek: Based on capture of 90,331 0+ chinook fry, estimated total outmigration past screw trap was 266,977.

APPENDIX B

SAMPLING SITES

Figure B-1

Soos Creek Screw Trap

River Mile 0.9

King County Collection Site, 2003

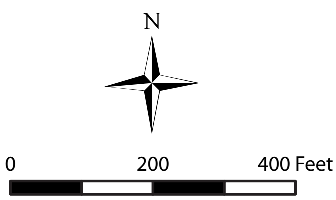

Photo: *King County 2000 Emerge image set.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0402_W9JSS_SoosCr.eps LPRE*

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Soos Creek Screw Trap (Figure B-1, Continued)

Habitat: Freshwater Stream

Location: Soos Creek RM 0.9
N 47° 18.42 W122° 09.54

(Soos Creek enters the Green River at RM 33.8)

Gear: Standard five foot diameter E.G. Solutions Inc. screw trap

Salinity: 0.0 ppt

Substrate: The stream bed is composed of small gravel and sand. The trap was anchored in a fairly swift (3-4 fps) riffle. The ordinary high stream width is about 7 meters.

Riparian: The adjacent banks have been hardened with large angular rock. Some deciduous trees and shrubs growing along narrow strip between creek and the hatchery shop infrastructure.

Figure B-1a. *Soos Creek screw trap at RM 0.9, installed on January 29, 2003 for the WRIA 9 Juvenile Salmonid Studies.*

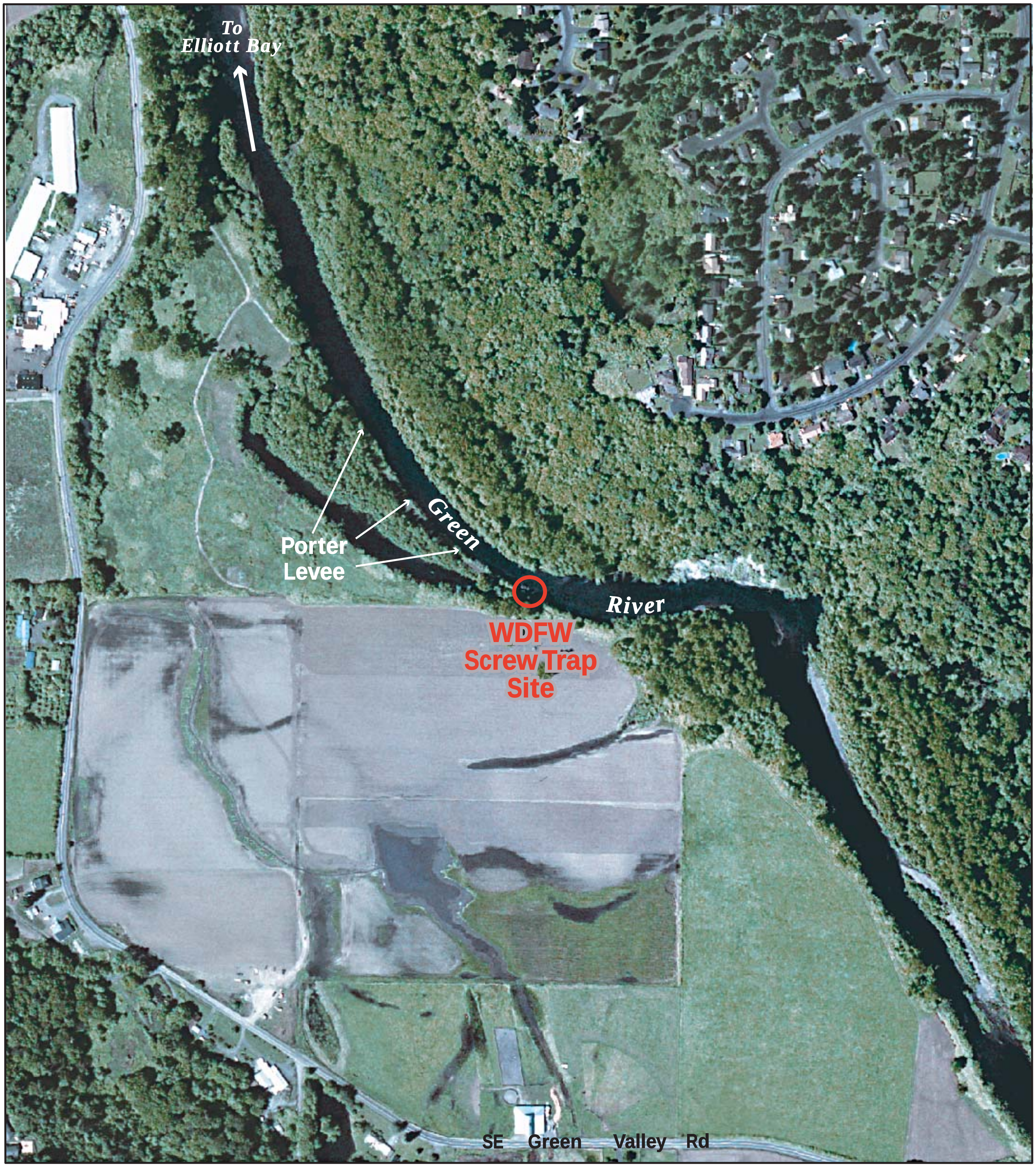

Figure B-2

Washington Department of Fish and Wildlife Screw Trap

River Mile 34.5

WDFW 2000-2003

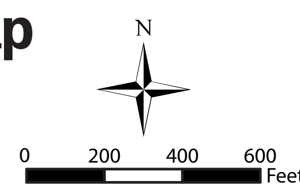

Photo: *King County 2000 Emerge image set.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0402_W9JSS_WDFW.eps LPRE*

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Washington Department of Fish and Wildlife Screw Trap (Figure B-2, Continued)

Habitat: Freshwater River

Location: Green River RM 34.5
N 47° 17.36 W 122° 09.54

Gear: The trap is a customized five foot diameter E.G. Solutions Inc. screw trap with large pontoons, retractable fish hold box and work shed. The hold box can be completely lifted above the river flow to reduce drag during installation or to help avoid damage during high flows.

Salinity: 0.0 ppt

Substrate: The river bed is composed primarily of cobble and gravel. The trap was positioned near the tail-out of a swift (6-8 fps)left bank riffle. The ordinary high river width at this location is about 20 meters.

Riparian: The left bank is a hardened levee (Porterhouse Levee) constructed of large angular rock. Land use near the trap is a combination of agriculture and park. Some deciduous and coniferous trees overhanging the reach, especially on the right bank.

***Figure B-2a**. Modified screw trap used by WDFW on Green River RM 34.5 from 2000 to 2003.*

Figure B-3

Kent Screw Trap

River Mile 18.0

King County 2003

N

0 100 200 300 Feet

Photo: *King County 2000 Emerge image set.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0042_W9JSS_Kent.eps LPRE*

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Kent Screw Trap (Figure B-3, Continued)

Figure B-3a. Installing the screw trap on the Green River near the 212th Street Bridge in the City of Kent on May 8, 2003. WRIA 9 Juvenile Salmonid Survival Study.

Habitat: Freshwater River

Location: Green River RM 18.0
N 47° 24.44 W 122° 15.51

Gear: The standard five foot diameter E.G. Solutions Inc. screw trap

Salinity: 0.0 ppt

Substrate: The river bed below the trap is composed of gravel, cobble and some boulders. Below the initial layer of stream material the bed is a conglomerate of clay and wood debris. The river has cut into this conglomerate material in the area allowing for the creation of some deep, narrow pools. The trap is placed in a tail-out of right bank riffle with moderately swift (3-4fps) water velocity. The ordinary high river width at the site is is about 20 meters.

Riparian: The trap location was about five meters downstream of the 212th Street Bridge and the banks have been hardened with angular rock to protect the footings. Vegetation is absent immediately under the bridge but Willows, Himalayan blackberry and reed canary grass dominate in the areas immediately outside of the bridge footprint. Both banks in this reach of the river have been heavily protected from flood erosion by rock revetments.

Observations: A five to six foot sturgeon was observed about 150 meters upstream of the 212th bridge in late June on two occasions.

Figure B-4

Marriott

River Mile 13.1
King County 2003

Best Western

River Mile 13.0
King County Index 2001, 2002, 2003

N

0 100 200 300
Feet

Photo: *King County 2002 ortho image set.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0042_W9JSS_BestWest.eps LPRE*

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure B-4a. Marriott sampling site beach on the Green River at RM 13.1. WRIA 9 Juvenile Salmonid Survival Study 2003.

(Figure B-1, Continued)

Marriott

Habitat: Tidal Freshwater

Location: Green River RM 13.1
N 47° 27.32 W 122° 14.44

Gear: Fyke net and baited pots

Salinity: 0.0 ppt

Substrate: The river bed is composed of sand. The gently sloping left bank beach is adjacent to a deep right bank pool in this unusually wide location. The ordinary high water width of the river is about 30 meters. The beach comes under tidal influence the water elevation can vary by .6 meters and velocities by two feet per second during low flows and high tides. The flow velocity slows during incoming tides but they have not been observed to reverse. Mean flow velocity at this site is three feet per second.

Riparian: Both banks have been hardened with rock for flood protection. A ten meter strip of vegetation lies between the river and the heavily urbanized shoreline (motels, office buildings, roads). The vegetation array is dominated by Himalayan blackberry, willows, reed canary grass and occasional cottonwood and alder trees.

Observation: In the winter 2003, juvenile Chinook appear to rear in area during periods of moderate to low flows (1,000 to 1,700 cfs) but are no longer observed after flows of greater than 2,500 cfs. The area appears to become restocked by juvenile Chinook after the higher flows reside and the aggregation persists until the next freshet.

Figure B-4b. Best Western beach sampling site on the Green River at RM 13.0. WRIA 9 Juvenile Salmonid Survival Study 2003.

Best Western

Habitat: Tidal Freshwater

Location: Green River RM 13.0
N 47° 27.32 W 122° 14.52

Gear: River seine, fyke net and baited pots

Salinity: 0.0 ppt

Substrate: Bed composed of sand. This right bank, gently sloping beach is adjacent to a deep left bank lateral scour pool. The site is in a reach near the upstream extent of tidal influence. Tide action is most pronounced during low flows and high tides, during theses times the water elevation can vary by .6 meters and velocities by 2 fps. There was always a positive downstream flow during all sampling events with a mean velocity of 3 fps. The ordinary high water width of the river is river is about 25 meters. Old pilings are still embedded into the substrate immediately across from the beach in the deep lateral pool and in mid channel about 20 meters upstream of the beach. The ordinary high water marks at the site are about 100 meters wide.

Riparian: Both banks have been hardened with rock for flood protection. A 10 meter strip of vegetation lies between the river and the heavily urbanized shoreline (motels, office buildings, roads). The vegetation array is dominated by Himalayan blackberry plus willows, reed canary grass and occasional cottonwood and alder trees.

Observation: The beach becomes entirely submerged with flows of 2,500 cfs and greater making seining inefficient at those times.

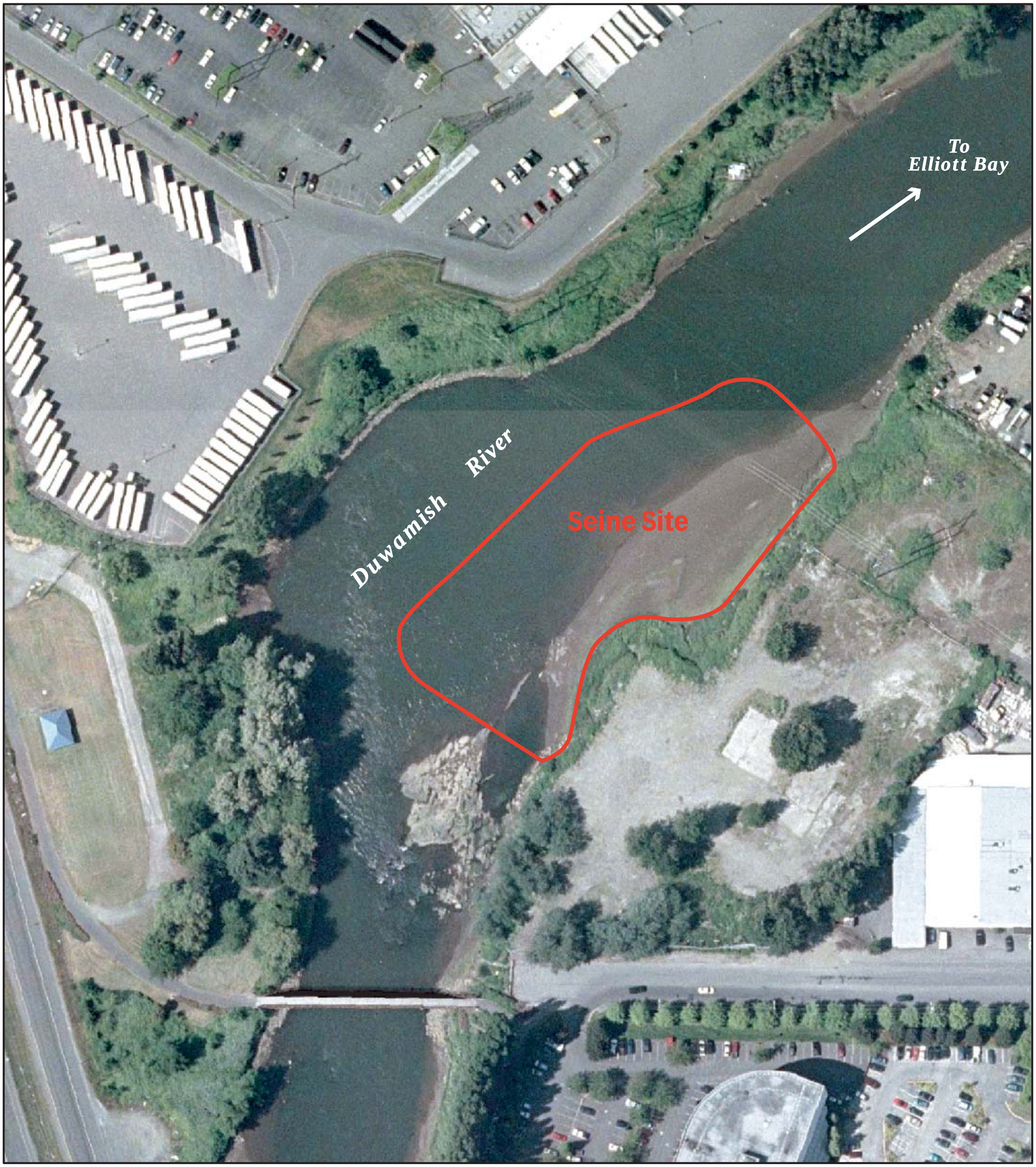

Photo: King County 2002 USGS image set.

Note: Approximate site locations and sizes are shown; not to scale.

Produced by: WLRD Visual Communications and GIS Unit

File: 0312_W9JSS_Trimaran.eps LPRE

Figure B-5

Trimaran

River Mile 6.5

King County Index 2002, 2003

N

0 300 Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Trimaran (Figure B-5, Continued)

Habitat: Estuarine Transition Zone

Location: Duwamish River RM 6.5 N 47° 30.13 W 122° 17.46

Gear: River seine

Salinity: Salinity varies from 0.0 to 30.0 ppt with depth, tide and river flow. The usual winter/spring upstream extent of the saltwater wedge ends near this site.

Substrate: Bed composed of mud and sand. Several large water logged trees lie parallel to the shore and submerged at moderate and higher tides. River elevations are controlled by the tide at this location. An impressive riffle forms over bedrock immediately upstream of the seining location at low tides. This riffle helps to form a large eddy at the site. The reach becomes difficult to navigate at low flows and negative tides due to numerous embedded logs, piles and sand bars.

Riparian: A narrow strip along both banks composed mostly of blackberry and some trees along the left bank. A patch of sedge (*Carex sp.*) lies along the upper beach from about +8 to +11 MHHW. Area is heavily urbanized and a powerline right of way is immediately downstream. Angular rock and some tires are used to armor the banks near the site.

Observation: This site had the highest chinook catches of any index site in 2003. Yearling and subyearling chinook were captured at this site in January.

Figure B-5a. Trimaran sampling site on the left bank of the Duwamish River at RM 7. Crew in process of drifting the river seine in June 2002. WRIA 9 Juvenile Salmonid Survival Study.

Figure B-5b. Rapids form immediately upstream of the Trimaran sampling site on the Duwamish River at low tide during the late spring, 2003. WRIA 9 Juvenile Salmonid Survival Study.

Figure B-6

Turning Basin

River Mile 5.5
King County 2003
Taylor Associates 2002, 2003

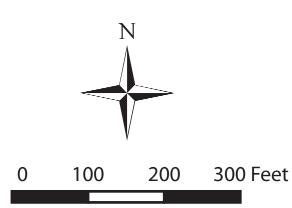

Photo: *King County 2000 Emerge image set.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0312_W9JSS_TurnBasin.eps LPRE*

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Turning Basin (Figure B-6, Continued)

Habitat: Estuarine Transition Zone

Location: Duwamish River RM 5.5 N 47° 30.43 W 122° 18.08

Gear: PSP seine and river seine

Salinity: Varies from 0.0 to 30.0 ppt with depth, tide and river flow.

Substrate: The bed is composed of mud on a gently sloping beach that leads waterward to a deep, routinely dredged channel. The area is one of the widest parts of the Duwamish River resulting in flow low velocity. The ordinary high water width at the site is about 200 meters.

Riparian: Areas landward of the seining beach have been restored with native vegetation and the upper intertidal reaches have established narrow strips of sedge (*Carex sp.*) and other salt tolerant wetland vegetation. Parking lots, industry and highways dominate the shorelines beyond the hardened banks.

Figure B-6a. *Biologists carrying buckets of fish for data processing through the mudflats at the Turning Basin on the Duwamish River for the WRIA 9 Juvenile Salmonid Survival Study in the spring, 2003.*

Figure B-6b. *Biologists pulling in the bag of the Puget Sound Protocol net at the Turning Basin on the Duwamish River for the WRIA 9 Juvenile Salmonid Survival Study in the spring, 2003.*

Photo: King County 2000 Emerge image set.

Note: Approximate site locations and sizes are shown; not to scale.

Produced by: WLRD Visual Communications and GIS Unit

File: 0312_W9JSS_Pitbull.eps LPRE

Figure B-7

Pit Bull

River Mile 3.5

King County Supplemental 2003

N

0 100 200

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Pit Bull (Figure B-7, Continued)

Habitat: Estuarine Mudflat

Location: Duwamish River RM 3.5 N 47 ° 31.54 W 122 ° 18.08

Gear: River seine

Salinity: Varies from 2 to 30 ppt depending on depth, tide and river flow.

Substrate: The site is a small pocket beach that was created in conjunction with the Duwamish River Park. The beach has a gentle slope until it meets an offshore dredged channel. The bed is composed of eroding mud exposing some angular rock and other debris. This is a heavily urbanized portion of the watershed with numerous on water developments (piers, marinas, etc.) constricting nearby beach habitat. The river is about 150 meters wide at this location.

Riparian: The area immediately upland of the beach has been landscaped with grass and a few trees as part of the park amenities. The banks near the site have been hardened with very narrow strips of mostly exotic vegetation along the top.

Figure B-7a. *The Pit Bull pocket beach restoration sampling site in the Duwamish River for the for the WRIA 9 Juvenile Salmonid Survival Study in the spring, 2003.*

Figure B-7b. *Heavily industrialized shoreline immediately downstream of Pit Bull beach in the spring 2003.*

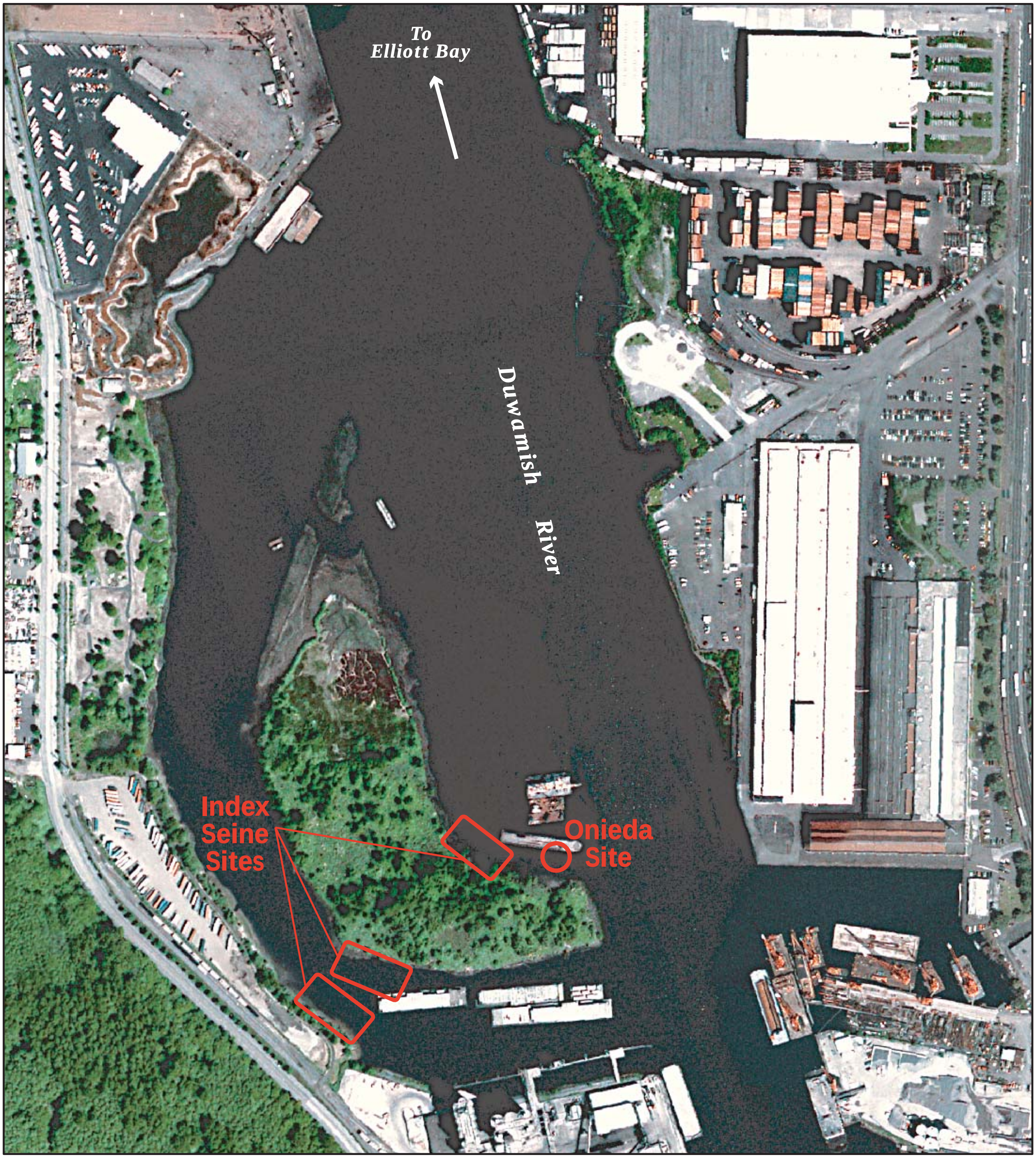

Figure B-8

Kellogg Island

River Mile 1.0

King County Index 2002-2003
King County Onieda Trap Net 2003
Taylor Supplemental 2002, 2003

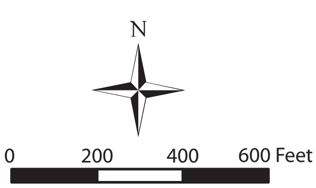

Photo: *King County 2000 Emerge image set.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0312_W9JSS_Kellogg.eps LPRE*

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Water and Land Resources Division

Kellogg Island (Figure B-8, Continued)

Figure B-8a. Preparing to re-anchor the Onieda net to piling after processing a days catch at Kellogg Island. WRIA 9 Juvenile Salmonid Survival Study 2003.

Habitat: Estuarine Mudflat

Location: Duwamish River RM 1.0
N 47° 33.26 W 122° 20.45

Gear: River seine, PSP seine, Onieda trap net

Salinity: The salinity varies from 7 to 30 ppt depending on depth, tide and river flow.

Substrate: The island and surrounding sand/mud beach was at least partly constructed from Duwamish River suction dredge spoils. The beaches on the east side slope gradually to a subtidal dredged channel and is exposed to erosive boat wakes. The west side beaches become exposed or nearly exposed at tides of –2 foot (MLLW=0.0) elevation and are protected from boat wakes making for very calm, low velocity conditions. Very soft mucky sediment is present on the west side and a filamentous alga, probably *Enteromorpha spp* proliferates in the late spring and summer. The beaches on both sides are strewn with various ship and pier debris.

Riparian: The island uplands are home for a thick growth of native and exotic plants with Red Alder, Pacific Madrone and willow trees visible. At the north end of the island a patch of Broad-leaved Cattail (*Typha latifolia*) is established. The outside banks of the river are hardened and industry is located upland.

Observation: Even with some obvious habitat deficiencies, this is the best juvenile salmonid rearing habitat in the lower Duwamish prior to entering Elliott Bay.

Figure B-9

Terminal 5 (T-5)

River Mile 0.0

Taylor Associates 2002-2003

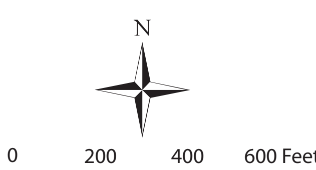


Photo: *King County 2002 orthophotos from USGS.*

Note: *Approximate site locations and sizes are shown; not to scale.*

Produced by: *WLRD Visual Communications and GIS Unit*

File: *0312_W9JSS_Term5.eps LPRE*

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Terminal Five (T-5) (Figure B-9, Continued)

Habitat: Nearshore Marine

Location: Duwamish River (West Waterway)
RM 0.0 N 47 ° 35.04 W 122 ° 21.40

Gear: PSP seine

Salinity: A thin layer of brackish (7- 20 ppt) may occur at high flows but this site is primarily marine with salinities of up to 30 ppt dominating the water column.

Substrate: Composed of gravel and sand lying between or near large commercial peirs.

Riparian: Banks protected with large angular rock, narrow strip of vegetation planted at top of bank.

Comments: This site was seined exclusively by Taylor Associates, a consultant for the Port of Seattle.

Figure B-9a. *Terminal 5 Seining Site.*

Photo: King County 2000 Emerge image set.

Note: Approximate site locations and sizes are shown; not to scale.

Produced by: WLRD Visual Communications and GIS Unit

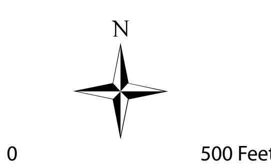
File: 0312_W9JSS_Slip27.eps LPRE

Figure B-10

Slip 27

River Mile 0.0

Taylor Associates 2002, 2003



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Slip 27 (Figure B-10, Continued)

Habitat: Nearshore Marine

Location: Duwamish River (East Waterway)
RM 0.0   N 47° 34.44   W 122° 20.30

Gear: PSP seine

Salinity: A thin layer of brackish (7- 20 ppt) may occur at high flows but this site is primarily marine with salinities of up to 30 ppt dominating the water column.

Substrate: Inside a commercial slip.

Riparian: Steep rock wall with commercial pier upland.

Comments: This site was seined exclusively by Taylor Associates, a consultant for the Port of Seattle.

Figure B-10a. *Retrieving the net at Slip 27.*

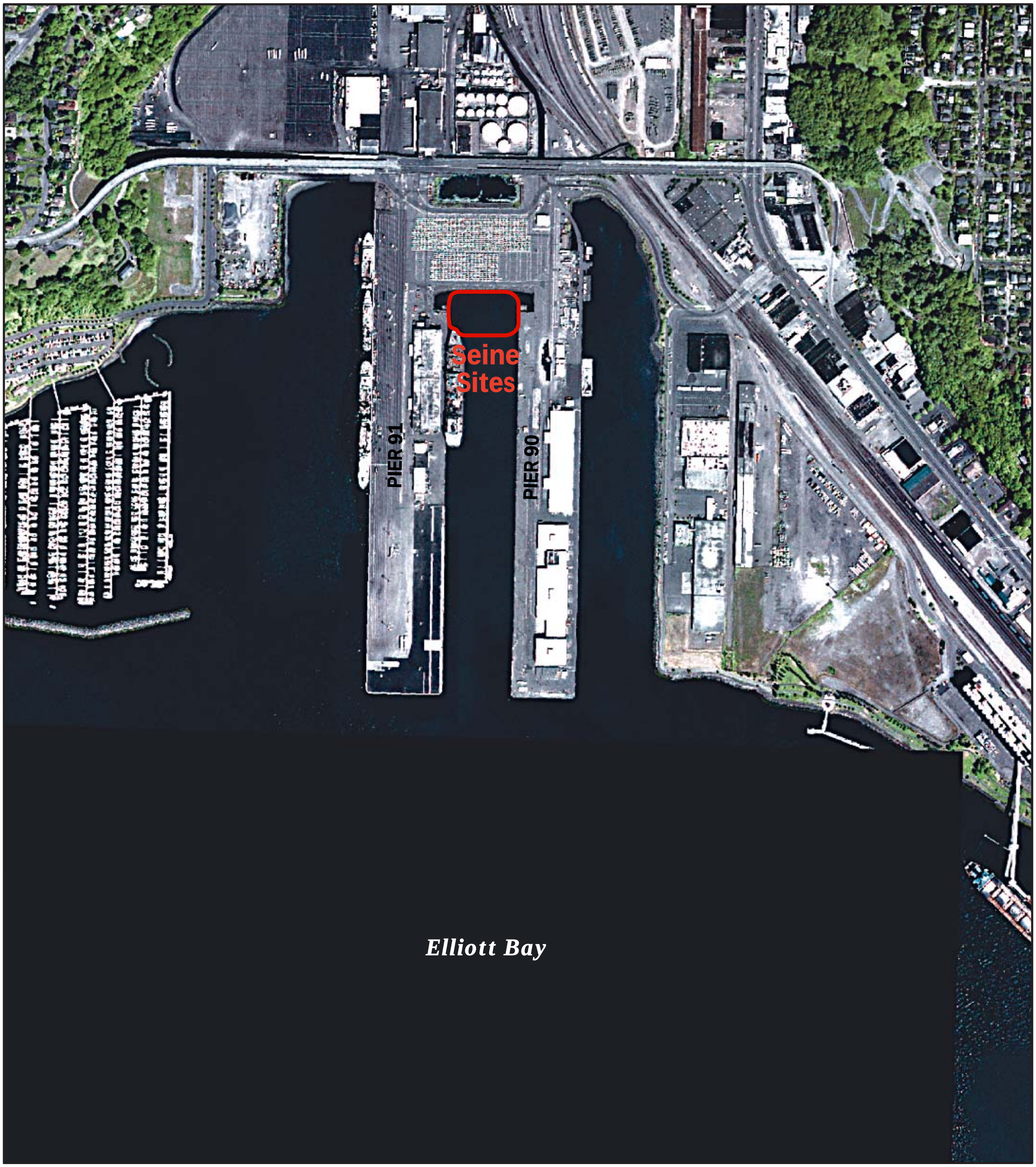


Photo: King County 2000 Emerge image set.

Note: Approximate site locations and sizes are shown; not to scale.

Produced by: WLRD Visual Communications and GIS Unit

File: 0312_W9JSS_Pier9091.eps LPRE

Figure B-11

Pier 90/91

Elliott Bay

Taylor Associates 2002

N

0 400 800 Feet

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Pier 90/91 (Figure B-11, Continued)

Habitat: Nearshore Marine

Location: Elliott Bay (northeast shoreline)
N 47° 37.50 W 122° 22.42

Gear: PSP seine

Salinity: 28 to 30 ppt

Substrate: Located inside of commercial slip.

Riparian: Narrow strip of vegetation at top of armored bank.

Comments: This site was seined exclusively by Taylor Associates, a consultant for the Port of Seattle.

Figure B-11a. *Pier 90-91 seining site.*

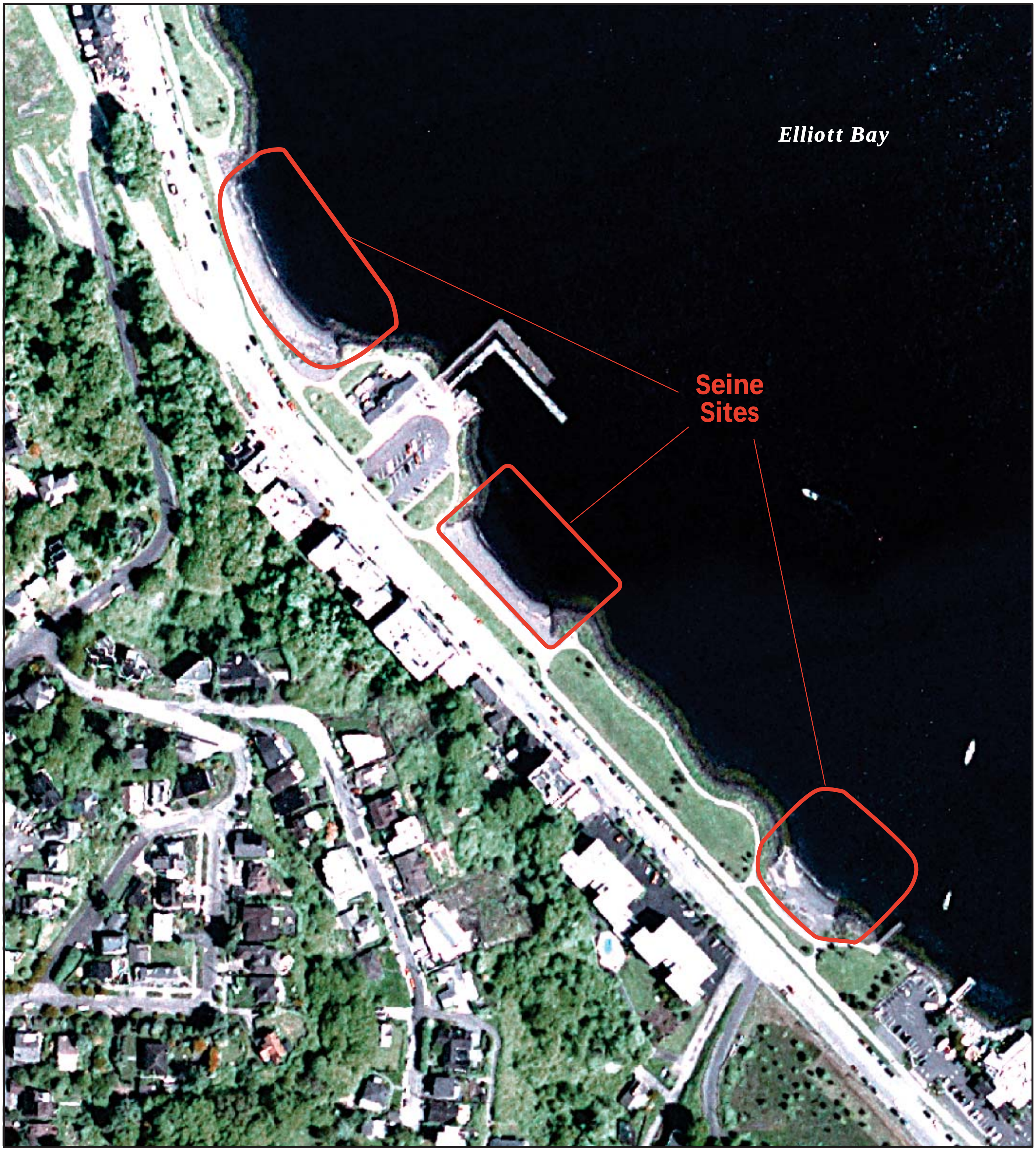


Photo: King County 2000 Emerge image set.

Note: Approximate site locations and sizes are shown; not to scale.

Produced by: WLRD Visual Communications and GIS Unit

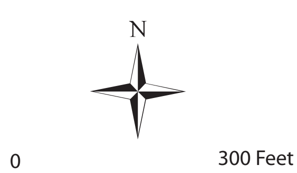
File: 0312_W9JSS_Seacrest.eps LPRE

Figure B-12

Seacrest

Elliott Bay

King County Index 2003



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Seacrest (Figure B-12, Continued)

Figure B-12a. River seining Seacrest pocket beach for the for the WRIA 9 Juvenile Salmonid Survival Study in the spring, 2003.

Habitat: Nearshore Marine

Location: Elliott Bay (southwest shoreline)
N 47° 35.16 W 122° 22.39

Gear: River seine

Salinity: 28 to 30 ppt

Substrate: Three small (40-60 meter long) man made, fairly steep gradient pocket beaches composed of cobble and gravel. Some submerged piling lay offshore at approximately -5 foot (MLLW=0.0) tide elevation at the center seining location.

Riparian: The banks are built of angular rock and a maintained trail and grass strip lies immediately landward.

Observations: Large concentration of Chinook juveniles seen inside the L-shaped dock during May through June. A turbidity plume from the Green Duwamish River that was produced during late January and early February 2003 high flows does not circulate towards this beach. The plume circulates north east towards downtown Seattle and West Point.

Photo: King County 2000 Emerge image set.

Note: Approximate site locations and sizes are shown; not to scale.

Produced by: WLRD Visual Communications and GIS Unit

File: 0312_W9JSS_Alki.eps LPRE

Figure B-13

Alki

Elliott Bay Nearshore

King County 2003

King County
Department of Natural Resources and Parks
Water and Land Resources Division

Figure B-13a. Alki beach sampling site (looking to the east) studied during the for the WRIA 9 Juvenile Salmonid Survival Study in the spring, 2003.

Alki (Figure B-13, Continued)

Habitat: Nearshore Marine

Location: Elliott Bay (southwest shoreline)
N 47° 35.11 W 122° 23.58

Gear: River seine

Salinity: 28 to 30 ppt

Substrate: A sand flat lies waterward of a moderately sloped foreshore beach berm composed of gravel and sand. The sand flat was exposed at tides of +1 foot (MLLW = 0.0) tide elevation and extends at least 200 meters from the berm.

Riparian: A popular recreational sand beach lies landward of the site.

APPENDIX C

USACE PIT TAG DRAFT LETTER REPORT

E-mail received from Fred Goetz (UACOE) on December 23, 2003.

Passive Integrated Transponders (PIT tags)

Passive-integrated-transponders (PIT-tags) were evaluated as a method to track juvenile chinook salmon migration time from the point of marking to the point of recapture in the estuary. PIT-tags have been used in the Lake Washington basin since 2000 and have provided a variety of metrics on travel time or residence time, migration timing to the estuary, and survival estimates. PIT-tags have been used in the Lake Washington General Investigation (GI) to determine the migration timing and residence time of juvenile chinook salmon (>60 mm) migrating through the Lake Washington basin. Natural reared and hatchery juvenile chinook salmon were marked at the WDFW screw trap at RM 33.8 (2000 fish-See Companion Permit Application for Screw-trap at the Green River) and at the Soos Creek Hatchery in late May and June.

For this study, tagging was conducted with portable PIT tagging stations designed for field use. Components of each station include electronic balance, digitizer, tag detector, and automatic tag injector. The automatic tag injector uses a pushrod system, to inject tags into the fish. Government equipment from the Lake Washington GI Study, was provided to mark fish and to identify tagged fish in the estuary. The Corps, WDFW, King County staff supervised or performed all PIT tagging following explicit fish handling, tagging, and release procedures developed by NMFS over the past 15 years (Matthews et al. 1986; Prentice et al. 1990: Achord et al. 1996; Matthews et al. 1997; Connor et al. 1998). Dye marking and fin clips were supervised by the same staff. The summary of the 2002 Green River pilot tagging efforts is shown in Table 3.

Based on previous work with capture of sub-yearling chinook in the Columbia River reservoirs and tributaries, PIT tagging (and fluorescent-dye marking) ceased when ambient water temperatures exceed 17 C in tributary streams Green River (Achord et al. 1998; Connor et al. 1998). Fish handling for tagging/marking purposes will follow procedures described in Matthews et al. (1986). In shallow water or confined areas, chinook salmon handled for anything other than species identification will be dipped with a hand-net fitted with a water tight bag (sanctuary net) permitting water to water transfer. Other studies have tagging juvenile chinook as small as 50 and 55 mm, for this study we will use a minimum fish size of 65 mm (Prentice et al. 1990; Achord et al. 1998).

All PIT-tagged fish were anesthetized in tricaine (MS-222, about 40 mg/l). Anesthetized fish that are injured, descaled, or less than 60 mm fork length were sorted and returned. Each remaining chinook was injected with a PIT tag according to the technique described by Prentice et al. (1990). Tagged fish were then passed through the detector loop, which enters the tag code into the computer, placed on the electronic balance and the weight automatically recorded in the computer. Fish placed on the digitizing board, which activates an electronic stylus at the fork of the tail, and the length in mm is recorded. Tagged fish were allowed to recover for a minimum of 30 minutes in a bucket or larger holding container.

Residence Time

Residence time of fin clipped chinook and coho salmon in the restoration sites was calculated per release date to recapture time. This data will provide an indication of the time fish spend in one or more restoration sites: Note, most of the off-channel sites fully dewater during low ebb tide whereby all fish within the site are pushed out of the site. To re-enter the site the fish must do so volitionally or remain very near to the outlet channel entrance to be pushed back into the site during the next flood tide.

Residence time of individual PIT-tagged fish was determined from the time of release at either Soos Creek Hatchery or the screw trap and recapture between RM 13 to the lowest restoration site at RM 1. Residence time of individually PIT-tagged chinook salmon was be calculated. These data will provide an indication of time spent between the beginning of Lower Green River (RM 32-33.8) and the end of the Duwamish Estuary.

Passive Integrated Transponders (PIT tags)
Originally up to 5000 fish were planned for PIT-tagging and release, however, due to late scheduling and few natural reared fish of sufficient size, only a total of 1248 fish, 1041 hatchery and 207 wild, were tagged and released in June (Table 4).

Paul DeVries, R2 Resource Consultants, reported on the tag recaptures from the Duwamish Estuary. A total of three hatchery chinook were recaptured by beach seine at two sites - Herrings House restoration site and the Trimaran beach seining location (Table 6). These fish were all released on June 7 from Soos Creek Hatchery. They were recaptured on three separate dates - June 11, June 12 and June 20. The recaptures were 4, 5, and 13 days post release. The fish recaptured on June 20 had grown from 79 mm to 84 mm over 13 days or about 0.4 mm/day. The river travel distance is approximately 32 miles from Soos Creek to RM 2 at Herrings House. The three recaptures represent a 0.3% detection rate (recapture rate), which would require at least 320 fish be tagged in a group in order to collect one PIT tagged fish in the Duwamish estuary. To get 20 fish for a crude survival estimate could therefore require around 6400 tagged fish in a release group (assuming a second control group is released slightly upstream of the sampling point to get at capture efficiency). The low recapture rate and cost of marking by PIT-tagging appears prohibitive compared to other means.

Table C-1. Summary of PIT-tag detections in the Duwamish estuary in 2002.

Tag Number	Release Location	Release Date	Recapture Location	Date	Time	Length at Tagging/Capture
3D9.1BF1423036	Soos Crk Hatchery	June 7	Herrings House	June 11	0830	96 mm/NA
3D9.1BF141B801	Soos Crk Hatchery	June 7	Herrings House	June 12	0115	84 mm/NA
3D9.1BF14B22E4	Soos Crk Hatchery	June 7	Trimaran	June 20	1320	79/84 mm

APPENDIX D

FISH CATCH TABLES

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Table D-1. 2003 WRIA 9 Juvenile Salmonid Survival Study River seine sampling effort and combined (natural and hatchery) subyearling Chinook catch by week.

Site Name:	Best Western		Best Western		Codiga Farms		Trimaran		Trimaran	
Gear:	River seine		River seine		River seine		River Seine		River Seine	
RM:	13		13		8.5		7		7	
	Index		supplemental		supplemental		index		supplemental	
Week	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings
1/19/2003	3	1	1	0						
1/26/2003							2	24		
2/2/2003										
2/9/2003	3	1	5	15			3	0		
2/16/2003	3	11	1	0			3	198	4	40
2/23/2003	3	0	6	5	3	6	3	72	4	422
3/2/2003	3	0					3	130	9	88
3/9/2003							2	0		
3/16/2003	3	2					3	0		
3/23/2003	3	0					3	3	3	17
3/30/2003	3	8					3	11	3	1
4/6/2003	3	75					3	43	1	14
4/13/2003	3	0	2	0	1	0	3	105		
4/20/2003	3	1			1	0	3	12	1	1
4/27/2003	3	2					3	59	1	12
5/4/2003	3	4					3	51		
5/11/2003	3	56					3	72		
5/18/2003	3	2	2	138	2	18	3	34	4	89
5/25/2003	3	5					3	348		
6/1/2003	3	10	3	40			3	158	3	123
6/8/2003	3	13					3	52	3	31
6/15/2003	3	6	1	0			3	38	1	13
6/22/2003	3	0					3	11	2	10
6/29/2003										
7/6/2003	3	0					3	0		
7/13/2003										
7/20/2003							3	0		
7/27/2003										
8/3/2003							3	0		
8/10/2003										
Totals:	63	197	21	198	7	24	70	1421	39	861

Table D-1 continued horizontally

Site Name:	**Pit Bull**		**Kellogg Island**		**Kellogg Island**		**Seacrest**		**Seacrest**	
Gear:	**River Seine**		**River Seine**		**River Seine**		**River Seine**		**River Seine**	
RM:	**3.5**		**1**		**1**					
Method*:	**supplemental**		**index**		**supplemental**		**index**		**supplemental**	
Week	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings
1/19/2003			2	1	1	0	1	0		
1/26/2003			2	1			2	1		
2/2/2003										
2/9/2003							1	27		
2/16/2003										
2/23/2003										
3/2/2003					1	25				
3/9/2003	1	27	3	20	2	0	3	0		
3/16/2003	1	0	3	13	3	6	3	0		
3/23/2003	2	21	3	0			3	0		
3/30/2003	2	30	3	0			3	0		
4/6/2003	1	10	3	2			3	0		
4/13/2003	2	3	3	11			3	0		
4/20/2003	2	15	3	1			3	0		
4/27/2003	1	8	3	3			2	0		
5/4/2003			3	0			3	0		
5/11/2003			3	2			3	1		
5/18/2003	2	8	3	6			3	20	1	3
5/25/2003			3	258			3	18		
6/1/2003			3	34			3	47		
6/8/2003			3	10			3	67		
6/15/2003			3	9	5	9	3	13		
6/22/2003			3	5	1	0	3	3	1	0
6/29/2003										
7/6/2003			3	2			3	11		
7/13/2003										
7/20/2003			3	0			3	5		
7/27/2003										
8/3/2003			3	0	1	0	3	1		
8/10/2003										
Totals:	14	122	61	378	14	40	60	214	2	3

Table D-1 continued horizontally

Site Name:	Alki Beach		Alki Beach		Misc.*	
Gear:	River seine		River seine		River seine	
RM:					various	
Method:	index		supplemental		supplemental	
Week	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings
1/19/2003	1	0				
1/26/2003	1	0			1	0
2/2/2003						
2/9/2003	1	2				
2/16/2003						
2/23/2003					2	610
3/2/2003						
3/9/2003	3	0				
3/16/2003	3	0				
3/23/2003	3	0			7	153
3/30/2003	3	0			3	16
4/6/2003	3	0			1	15
4/13/2003	3	0				
4/20/2003	3	0				
4/27/2003	3	0			3	3
5/4/2003	3	2				
5/11/2003	3	2				
5/18/2003	3	0	3	25		
5/25/2003	3	4				
6/1/2003	3	17				
6/8/2003	3	0	3	9		
6/15/2003	3	2	2	31	2	1
6/22/2003	3	13			4	11
6/29/2003						
7/6/2003	2	1				
7/13/2003						
7/20/2003	3	4				
7/27/2003						
8/3/2003	3	0				
8/10/2003						
Totals:	50	47	8	65	20	809

*Sites include Marriott, Big Tire, Boat Launch, Diagonal Park, Seattle PI, and Turning Basin.

Table D-2. 2003 WRIA 9 Juvenile Salmonid Survival Study Puget Sound Protocol seine sampling effort and combined (natural and hatchery) subyearling Chinook catch by week.
All sets were made by Taylor Associates except for the ones indicated with a KC (King County only) or T&KC (joint Taylor Associates and King County effort).

Site Name:	Turning Basin		Kellogg Island		T-5		Slip 27		Misc.*	
RM:	5.5		1		0		0		various	
	supplemental		supplemental		supplemental		supplemental		supplemental	
Week	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings	sets	chinook subyearlings
1/19/2003										
1/26/2003										
2/2/2003										
2/9/2003			3	68	6	9	6	8	2(KC)	29
2/16/2003	3	235	3	18	6	6	6	0	6(KC)	12
2/23/2003	11	979	3	1	9	0	6	9		
3/2/2003	3	213	3	19	6	0	6	10		
3/9/2003	9(T&KC)	250	3	5	6	0	6	0		
3/16/2003	3(KC)	125								
3/23/2003	3	22	3	1	6	0	6	8		
3/30/2003										
4/6/2003	5(KC)	153								
4/13/2003	8(T&KC)	62	3	0	6	0	6	4		
4/20/2003	5(KC)	122								
4/27/2003	6(T&KC)	143	3	10	6	0	6	0		
5/4/2003										
5/11/2003	3	63	3	0	6	0	6	2		
5/18/2003										
5/25/2003	3	147	3	477	6	90	6	23		
6/1/2003										
6/8/2003	3	25	3	12	6	90	6	29		
6/15/2003										
6/22/2003	3	28	3	4	6	115	6	13		
6/29/2003										
7/6/2003	3	15	3	11	6	20	6	3		
7/13/2003										
7/20/2003	3	1	3	3	6	45	6	3		
7/27/2003										
8/3/2003										
8/10/2003										
Total:	74	2583	42	629	87	375	84	112	8	41

*Alki and Seacrest

Table D-3. 2003 WRIA 9 Juvenile Salmonid Survival Study sampling effort and combined (natural and hatchery) subyearling Chinook catch by week at the WDFW, Soos Creek and Kent screw traps.

Site Name	Soos Creek Screw Trap		Kent Screw Trap	
Gear	stock 5' screw trap		stock 5' screw trap	
RM	0.9 (enters Green River @ 33)		18	
Week	days	chinook subyearlings	days	chinook subyearlings
1/19/2003				
1/26/2003	3	8		
2/2/2003	4	130		
2/9/2003	5	1949		
2/16/2003	7	15361		
2/23/2003	7	7567		
3/2/2003	7	12293		
3/9/2003	7	6287		
3/16/2003	7	1243		
3/23/2003	6	206		
3/30/2003				
4/6/2003				
4/13/2003				
4/20/2003				
4/27/2003				
5/4/2003				
5/11/2003			6	101
5/18/2003			5	453
5/25/2003			5	492
6/1/2003			5	219
6/8/2003			6	172
6/15/2003			5	57
6/22/2003			4	26
6/29/2003				
7/6/2003				
7/13/2003				
7/20/2003				
7/27/2003				
8/3/2003				
8/10/2003				
Total:	53	45044	36	1520

*Days of operation assumed until WDFW provides more information. There were times when trap was not operated because of high flows, damage, and hatchery releases.

Table D-4. 2003 WRIA 9 Juvenile Salmonid Survival Study weekly sampling effort and combined (natural and hatchery) subyearling Chinook catch of the fyke nets and Onieda trap.

Site Name:	Marriott		Best Western		Kellogg Island	
Gear:	fyke net		fyke net		Onieda Trap	
RM:	13.1		13		2	
	supplemental		supplemental		supplemental	
Week	days	chinook subyearlings	days	chinook subyearlings	days	chinook subyearlings
1/19/2003						
1/26/2003						
2/2/2003					1	171
2/9/2003					3	9
2/16/2003			4	39	2	57
2/23/2003			2	41	5	18
3/2/2003	2	10	1	1	4	16
3/9/2003					4	4
3/16/2003					3	7
3/23/2003					3	3
3/30/2003					3	2
4/6/2003	3	0	3	17	3	0
4/13/2003					2	0
4/20/2003	3	0	3	7	3	1
4/27/2003	3	1			3	0
5/4/2003					2	0
5/11/2003					3	4
5/18/2003					3	0
5/25/2003					3	6
6/1/2003					3	1
6/8/2003					2	2
6/15/2003						
6/22/2003						
6/29/2003						
7/6/2003						
7/13/2003						
7/20/2003						
7/27/2003						
8/3/2003						
8/10/2003						
Total:	11	11	13	105	55	301

Table D-5. 2002 WRIA 9 Juvenile Salmonid Survival Study seine sampling effort and combined (natural and hatchery) subyearling Chinook by week.

Site Name:	**Best Western**		**Codiga Farms**		**Trimaran**		**Kellogg Island**		**Turning Basin**		**Misc. Duwamish**	
Gear:	**seine**		**seine**		**seine**		**seine**		**seine**		**seine**	
RM:	**13**		**8.5**		**7**		**1**		**5.5**		**near 10**	
Week	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook
27-Jan-2002	4	1			3	12						
3-Feb-2002	4	0					2	1				
10-Feb-2002	3	1			2	0	4	0				
17-Feb-2002	6	0					3	0				
24-Feb-2002	4	0			1	2	2	2				
3-Mar-2002	6	0					1	0				
10-Mar-2002	3	0			1	3	1	2				
17-Mar-2002	2	0			1	0	1	0				
24-Mar-2002	3	0			2	0	2	0				
31-Mar-2002	4	4			2	6	2	0				
7-Apr-2002	3	2			1	10	2	3				
14-Apr-2002	3	0			1	2	2	0				
21-Apr-2002	3	1			3	11	2	2				
28-Apr-2002	4	0			3	2	2	2				
5-May-2002	4	4			2	46	2	5				
12-May-2002	6	25			1	3	1	2				
19-May-2002	3	3			2	45	2	3				
2-Jun-2002	18	193	2	16	1	174					1	1
9-Jun-2002	19	234			4	527	2	367				
16-Jun-2002	6	22			14	404	4	14	16	149		
23-Jun-2002	10	120			5	200	2	15				
7-Jul-2002	4	2			6	52	4	36				
14-Jul-2002	4	0			4	2	6	6				

Table D-5 continued

Site Name:	Best Western		Codiga Farms		Trimaran		Kellogg Island		Turning Basin		Misc. Duwamish	
Gear:	seine		seine		seine		seine		seine		seine	
RM:	13		8.5		7		1		5.5		near 10	
Week	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook	sets	Total weekly chinook
28-Jul-2002	4	1			3		3	3				
11-Aug-2002					4		4	0				
25-Aug-2002					4		3	2				
8-Sep-2002					3		6	0				
17-Nov-2002					10							
Total:	157	613	2	16	87	1501	67	465	16	149	1	1

Table D-6. 2001 WRIA 9 Juvenile Salmonid Survival Study River seine sampling effort and combined (natural and hatchery) subyearling Chinook catch by week.

Best Western		
River seine		
Date	Sets	Chinook
5/8/2001	6	117
5/15/2001	6	200
5/22/2001	5	283
5/29/2001	7	171
6/4-5/2001	16	946
6/12/2001	7	305
6/19/2001	6	24
6/26/2001	7	32
7/3/2001	2	3
7/10/2001	4	16
7/24/2001	5	10
8/7/2001	2	0
8/23/2001	5	0
Total:	78	2107

Table D-7. 2003 WRIA 9 Juvenile Salmonid Survival Study total fish catch by species from sampling locations in the Green River.

Common Name	Genus/Species	Best Western River Seine	Marriott River Seine	Best Western Fyke	Marriott Fyke	Soos Screw Trap	Kent Screw Trap*
Chinook natural subyearling	*Oncorhynchus tshawytscha*	215	4	105	11	45044	382
Chinook hatchery subyearling	*Oncorhynchus tshawytscha*	180	7				1138
Chinook subyearling, origin undetermined	*Oncorhynchus tshawytscha*	7					
Chinook natural yearling	*Oncorhynchus tshawytscha*	1					
Chinook hatchery yearling	*Oncorhynchus tshawytscha*			3	1		
Coho natural subyearling	*Oncorhynchus kisutch*	1		4		4942	1
Coho natural yearling	*Oncorhynchus kisutch*	12		1		267	268
Coho yearling, origin undetermined	*Oncorhynchus kisutch*			1			
Coho hatchery yearling	*Oncorhynchus kisutch*	4		2			99
Coho - unchecked	*Oncorhynchus kisutch*						59
Cutthroat Trout	*Oncorhynchus clarki*	1				14	
Chum subyearling	*Oncorhynchus keta*	182		51	26	5	343
steelhead (unclip)	*Oncorhynchus mykiss*	7				19	22
Steelhead hatchery yearling	*Oncorhynchus mykiss*	1				2	12
Dace	*Rhinichthys spp.*	10	10	2		6	
Lamprey spp.	*Lampreta spp.*	3			1	27	63

Common Name	Genus/Species	Best Western River Seine	Marriott River Seine	Best Western Fyke	Marriott Fyke	Soos Screw Trap	Kent Screw Trap*
Mountain whitefish	*Prosopium williamsoni*	17			1		
Sculpin spp.	*Cottus spp.*	18		1		13	
Starry flounder	*Platichthys stellatus*	1					
Sucker spp.	*Castostomidae sp.*						7
Three-Spine Stickleback	*Gasterosteus aculeatus*	1		7		65	232

* An approximate 2 meter long sturgeon, Acipenser sp., was observed about ½ km upstream of the Kent screw trap on June 26 and 27, 2003.

Table D-8. 2003 WRIA 9 Juvenile Salmonid Survival Study total fish catch by species at sampling locations in the Duwamish River (RM 11.0 to 0.0).

Name	Genus/Species	Kellogg Island River Seine	Pit Bull River Seine	Trimaran River Seine	Turning Basin River Seine	Misc.* Supplemental Sites	Turning Basin PSP**	Kellogg Island Onieda Net
Chinook natural subyearling	*Oncorhynchus tshawytscha*	129	122	1597	794	12	665	292
Chinook hatchery subyearling	*Oncorhynchus tshawytscha*	289		685		16	1	9
Chinook subyearling, origin undetermined	*Oncorhynchus tshawytscha*							1
Chinook hatchery yearling	*Oncorhynchus tshawytscha*			10			3	
Chinook natural yearling	*Oncorhynchus tshawytscha*	1		10		28		
Coho natural yearling	*Oncorhynchus kisutch*	9	4	185	18		21	1
Coho hatchery yearling	*Oncorhynchus kisutch*	10	9	209		1	63	3
Coho natural subyearling	*Oncorhynchus kisutch*			5	2			
Coho yearling, origin undetermined	*Oncorhynchus kisutch*						118	
Chum subyearling	*Oncorhynchus keta*	1365	2863	2224	2239	19	6581	5520
Steelhead (unclip)	*Oncorhynchus mykiss*	2	1	2			2	
Steelhead hatchery yearling	*Oncorhynchus mykiss*		2	1	1		1	1
Pink subyearling	*Oncorhynchus gorbuscha*			1	2	1		1
Cutthroat Trout	*Oncorhynchus clarki*	1	2				6	
Bay pipefish	*Syngnathus griseolineatus*	3						10
Dace	*Rhinichthys spp.*			1		3		

Name	Genus/Species	Kellogg Island River Seine	Pit Bull River Seine	Trimaran River Seine	Turning Basin River Seine	Misc.* Supplemental Sites	Turning Basin PSP**	Kellogg Island Onieda Net
Gunnel spp.	*Pholis spp.*	2						6
Pacific Herring	*Clupea harengus pallasi*	1						145
Lamprey	*Lampreta spp.*			1				1
Pile perch	*Rhacochilis vaca*							7
Pacific sandlance	*Ammodytes hexapterus*	1						499
Sculpin spp.	*Cottus spp.*	297	29	67	6	12	38	225
Shiner Perch	*Cymatogaster aggregatta*	1762	3	68		25		4010
Surf smelt	*Hypomesus pretiosus*	55					4	44
Snake prickleback	*Lumpenus sagitta*	2						54
Pacific staghorn sculpin	*Leptocottus armatus*							6
Starry Flounder	*Platichthys stellatus*	63	10	334	8	4	28	42
Three-Spine stickleback	*Gasterosteus aculeatus*	480		420			1	1281
Striped Perch	*Embiotoca lateralis*							1
Sucker spp.	*Castostomidae sp.*		1	1			1	
Pacific tomcod	*Microgadus proximus*							51
Mountain Whitefish	*Prosopium williamsoni*	15	1	65	16		9	

* Locations include: Boatlaunch, Codiga Farms, and Diagonal Park.
** Includes King County or King County and Taylor Associates joint sampling only. Does not include solitary effort by Taylor Associates.

Table D-9. 2003 WRIA 9 Juvenile Salmonid Survival Study total fish catch by species at sampling locations in Elliott Bay.

Common Name	Genus/Species	Alki River Seine	Seacrest River Seine	Seattle PI River Seine	Alki PSP	Seacrest PSP
Chinook natural subyearling	*Oncorhynchus tshawytscha*	57	80		2	39
Chinook hatchery subyearling	*Oncorhynchus tshawytscha*	55	137			
Chinook hatchery yearling	*Oncorhynchus tshawytscha*	1	2			
Coho hatchery yearling	*Oncorhynchus kisutch*	7	9			
Coho natural yearling	*Oncorhynchus kisutch*	5	52			
Chum subyearling	*Oncorhynchus keta*	670	2563		2	
Steelhead (unclip)	*Oncorhynchus mykiss*	1				
Pink subyearling	*Oncorhynchus gorbuscha*	5	4		2	
Cutthroat Trout	*Oncorhynchus clarki*	1	13			
Bay pipefish	*Syngnathus griseolineatus*	1	4			4
Kelp greenling	*Hexagrammos decagrammus*	1				
Pacific sandlance	*Ammodytes hexapterus*	25	2			
Pacific staghorn sculpin	*Leptocottus armatus*	6	1			
Pile perch	*Rhacochilis vaca*		6			
Sculpin spp.	*Cottus spp.*	18	50	5	3	2
Shiner Perch	*Cymatogaster aggregatta*	198	18			
Starry Flounder	*Platichthys stellatus*	4	5		2	1
Striped Perch	*Embiotoca lateralis*		1			
Surf smelt	*Hypomesus pretiosus*	10	7			
Three-Spine stickleback	*Gasterosteus aculeatus*		1			
Flatfish misc.		6	3			
Larval fish misc.		1026				

Table D-10. 2002 WRIA 9 Juvenile Salmonid Survival Study total fish catch by species at the Best Western sampling site on the Green River.

Common Name	Genus/Species	Best Western
Chinook natural subyearling	*Oncorhynchus tshawytscha*	281
Chinook hatchery subyearling	*Oncorhynchus tshawytscha*	329
Chinook hatchery yearling	*Oncorhynchus tshawytscha*	1
Chinook unknown origin, subyearling	*Oncorhynchus tshawytscha*	2
Coho natural subyearling	*Oncorhynchus kisutch*	30
Coho hatchery subyearling	*Oncorhynchus kisutch*	2
Coho natural yearling	*Oncorhynchus kisutch*	2
Coho hatchery yearling	*Oncorhynchus kisutch*	5
Coho unknown origin	*Oncorhynchus kisutch*	4
Chum subyearling	*Oncorhynchus keta*	55
Cutthroat trout	*Oncorhynchus clarki*	1
Pink subyearling	Oncorhynchus gorbuscha	3
Rainbow trout	*Oncorhynchus mykiss*	1
Steelhead trout	*Oncorhynchus mykiss*	5
Unidentified trout subyearling	*Oncorhynchus spp.*	6
Dace	*Rhinichthys spp.*	61
Sculpin spp.	*Cottus spp.*	56
Starry Flounder	*Platichthys stellatus*	1
Three-spine stickleback	*Gasterosteus aculeatus*	263
Mountain whitefish	*Prosopium williamsoni*	50
Sucker spp.	*Castostomidae spp.*	1
River lamprey	*Lampetra ayresi*	6

Table D-11. 2002 WRIA 9 Juvenile Salmonid Survival Study total fish catch by species at sampling sites in the Duwamish River.

Common Name	Genus/Species	Codiga Farms	Kellogg Island	Turning Basin	Trimaran	Duwamish misc.
Chinook natural subyearling	*Oncorhynchus tshawytscha*	6	94	56	381	1
Chinook hatchery subyearling	*Oncorhynchus tshawytscha*	10	358	93	1100	
Chinook natural yearling	*Oncorhynchus tshawytscha*		2		3	
Chinook hatchery yearling	*Oncorhynchus tshawytscha*		11		17	
Coho natural yearling	*Oncorhynchus kisutch*		65		10	
Coho hatchery yearling	*Oncorhynchus kisutch*		159		3	
Coho natural	*Oncorhynchus kisutch*				1	
Coho hatchery	*Oncorhynchus kisutch*		209			
Unidentified trout subyearling	*Oncorhynchus spp.*				1	
Pink subyearling	*Oncorhynchus gorbuscha*		20		3	
Rainbow trout	*Oncorhynchus mykiss*		2			
Chum subyearling	*Oncorhynchus keta*		2,526	20	66	
Cutthroat trout	*Oncorhynchus clarki*		2		1	
Steelhead trout	*Oncorhynchus mykiss*		65		2	
Dace	*Rhinichthys spp.*				64	
Mountain whitefish	*Prosopium williamsoni*				29	
Pacific herring	*Clupea harengus pallasi*		7			
Pacific sand lance	*Ammodytes hexapterus*		3			
Sculpin spp.	*Cottus spp.*		148	25	51	
Shiner Perch	*Cymatogaster aggregatta*		4,751	29	900	
Snake prickleback	*Lumpenus sagitta*		6			
Starry Flounder	*Platichthys stellatus*		82	31	215	
Surf smelt	*Hypomesus pretiosus*				25	
Three-spine stickleback	*Gasterosteus aculeatus*		1,317	29	72	
Sucker spp.	*Castostomidae sp.*				1	

Table D-12. 2001 WRIA 9 Juvenile Salmonid Survival Study total fish catch by species at the Best Western sampling site on the Green River.

Common Name	Genus/Species	No. Captured
Chinook natural subyearling	*Oncorhynchus tshawytscha*	1,217
Chinook natural yearling	*Oncorhynchus tshawytscha*	18
Chinook hatchery subyearling	*Oncorhynchus tshawytscha*	710
Chinook hatchery yearling	*Oncorhynchus tshawytscha*	53
Chinook subyearling, origin unidentified	*Oncorhynchus tshawytscha*	296
Chinook yearling, origin unidentified	*Oncorhynchus tshawytscha*	1
Chum Salmon	*Oncorhynchus keta*	237
Coho natural subyearling	*Oncorhynchus kisutch*	23
Coho hatchery yearling	*Oncorhynchus kisutch*	4
Coho, origin unidentified	*Oncorhynchus kisutch*	10
Wild Steelhead/Rainbow Trout	*Oncorhynchus mykiss*	7
Hatchery steelhead/rainbow trout	*Oncorhynchus mykiss*	6
Unidentified trout subyearling	*Onchorhynchus spp.*	6
Mountain Whitefish	*Prosopium williamsoni*	79
Sculpin	*Cottus spp.*	26
Dace	*Rhinichthys spp.*	46
Three-Spine Stickleback	*Gasterosteus aculeatus*	20
Starry Flounder	*Platichthys stellatus*	9
Bass	*Micropterus sp.*	6
Lamprey	*Lampreta spp.*	1

Table D-13. 2001 to 2003 WRIA 9 Juvenile Salmonid Survival Study Chinook mortalities.

Year	Location	Gear	Natural/Hatchery	# morts	Totals
2001	Green River	River Beach Seine	Natural	5	2001: 5 Natural
2002	Green River	River Beach Seine	Hatchery	1	2002:
2002	Duwamish	River Beach Seine	Natural	1	21 Hatchery
2002	Duwamish	PSP	Natural	1	2 Natural
2002	Duwamish	PSP	Hatchery	20	1 Unknown
2002	Green River	River Beach Seine	Unknown	1	
2003	Duwamish	River Beach Seine	Natural	7	2003:
2003	Duwamish	Onieda net	Natural	6	461 Natural
2003	Green River	Fyke net	Natural	4	199 Hatchery
2003	Nearshore	Puget Sound BS	Natural	2	16 Unknown
2003	Duwamish	Puget Sound BS	Natural	10	
2003	Soos Creek	Spray Marking	Natural	301*	
2003	WRIA 9	Seine and trap	Hatchery	199**	
2003	WRIA 9	Seine and trap	Unknown	16**	
2003	WRIA 9	Seine and trap	Natural	131**	

*Estimated from spray marking mortality study (0.7% x 42,963 Chinook spray marked).
**Chinook were part of collection for otoliths, scales, and CWTs and from various sites.

Table D-14. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and catch of natural subyearling Chinook at index seining sites by week.

Week	Location	n	Mean	Min.	Max.	Total Captured
19-Jan-03	Best Western	1	45	45	45	1
	Kellogg	0	-	-	-	1
26-Jan-03	Trimaran	24	38	35	42	24
	Kellogg	0	-	-	-	1
	Seacrest	1	40	40	40	1
02-Feb-03	Kellogg	35	40	36	42	171
09-Feb-03	Best Western	16	41	38	44	16
	Kellogg	9	39	34	43	9
	Seacrest	27	40	35	43	54
	Alki	2	41	41	41	4
16-Feb-03	Best Western	50	42	33	49	50
	Trimaran	66	42	38	46	238
	Kellogg	20	42	37	45	57
	Seacrest	9	43	39	47	12
23-Feb-03	Best Western	46	42	38	50	46
	Trimaran	82	42	36	49	494
	Kellogg	18	41	37	48	18
02-Mar-03	Best Western	1	38	38	38	1
	Trimaran	98	43	30	49	218
	Kellogg	40	44	37	50	41
09-Mar-03	Kellogg	24	46	40	52	24
16-Mar-03	Best Western	2	41	40	42	2
	Kellogg	24	46	37	52	26
23-Mar-03	Trimaran	19	47	40	58	20
	Kellogg	3	54	53	55	3
30-Mar-03 Table D-14 continued	Best Western	7	47	44	51	8
	Trimaran	12	47	41	53	12
	Kellogg	2	49	49	49	2
06-Apr-03	Best Western	86	49	41	66	92
	Trimaran	57	60	49	76	57
	Kellogg	2	55.0	52	58	2
13-Apr-03	Trimaran	83	57	46	69	105
	Kellogg	11	66	57	85	11
20-Apr-03	Best Western	8	57	51	66	8

Week	Location	n	Mean	Min.	Max.	Total Captured
	Trimaran	13	58	49	65	13
	Kellogg	2	65	59	70	2
27-Apr-03	Best Western	2	56	51	60	2
	Trimaran	71	66	56	82	71
	Kellogg	3	76	68	84	3
04-May-03	Best Western	4	55	45	67	4
	Trimaran	51	69	58	83	51
	Alki	1	87	87	87	1
11-May-03	Best Western	54	68	50	81	55
	Trimaran	72	73	58	94	72
	Kellogg	6	69	59	79	6
	Seacrest	1	78	78	78	1
	Alki	1	86	86	86	1
18-May-03	Best Western	20	77	64	94	20
	Trimaran	62	79	57	119	62
	Kellogg	6	79	68	100	6
	Seacrest	14	85	76	103	15
	Alki	25	89	72	121	25
25-May-03	Best Western	1	72	72	72	1
	Trimaran	59	79	59	95	59
	Kellogg	17	82	72	107	17
	Seacrest	2	74	73	75	2
	Alki	2	73	68	78	4
01-Jun-03	Best Western	10	89	80	99	10
	Trimaran	40	78	63	95	42
	Kellogg	6	73	68	80	6
	Seacrest	7	80	69	96	7
	Alki	2	74	70	77	2
08-Jun-03	Best Western	3	82	70	92	3
	Trimaran	16	80	65	87	25
	Kellogg	3	75	72	79	3
	Seacrest	15	78	73	86	15
	Alki	1	81	81	81	1
15-Jun-03	Best Western	1	85	85	85	1
	Trimaran	26	84	73	96	26
	Kellogg	7	76	71	87	7

Week	Location	n	Mean	Min.	Max.	Total Captured
	Seacrest	5	82	78	87	5
	Alki	11	85	75	101	14
22-Jun-03	Trimaran	8	82	73	89	8
	Kellogg	4	79	77	86	4
	Seacrest	2	90	85	94	2
	Alki	4	85	80	93	4
06-Jul-03	Kellogg	1	110	110	110	1
	Seacrest	2	102	102	102	2
20-Jul-03	Seacrest	2	98	96	99	2
	Alki	1	100	100	100	1
03-Aug-03	Seacrest	1	107	107	107	1

Table D-15. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and catch of hatchery subyearling Chinook at index seining sites by week.

Week	Location	n	Mean	Min.	Max.	Total Captured
4-May-03	Alki	1	85	85	85	1
11-May-03	Best Western	1	71	71	71	1
	Alki	1	108	108	108	1
18-May-03	Best Western	121	82	59	107	121
	Trimaran	61	77	65	99	61
	Seacrest	8	108	80	118	8
25-May-03	Best Western	4	80	73	84	4
	Trimaran	76	82	64	99	289
	Kellogg	80	86	70	108	247
	Seacrest	12	73	60	83	16
	Alki	2	81	79	83	2
01-Jun-03	Best Western	40	88	70	109	40
	Trimaran	69	82	64	94	239
	Kellogg	29	77	67	94	29
	Seacrest	40	84	69	110	40
	Alki	15	76	69	85	15
08-Jun-03	Best Western	10	86	79	92	10
	Trimaran	52	82	67	94	58
	Kellogg	9	76	65	81	9
	Seacrest	51	79	69	90	52
	Alki	8	84	78	90	8
15-Jun-03	Best Western	5	85	81	90	5
	Trimaran	25	87	79	100	25
	Kellogg	11	80	72	87	11
	Seacrest	8	83	77	91	8
	Alki	16	87	76	108	19
22-Jun-03	Trimaran	13	85	75	98	19
	Kellogg	1	82	82	82	1
	Seacrest	1	100	100	100	1
	Alki	9	89	81	105	9
06-Jul-03	Kellogg	1	94	94	94	1
	Seacrest	9	102	89	122	9
	Alki	1	95	95	95	1
20-Jul-03	Seacrest	3	104	96	109	3
	Alki	3	103	99	107	3

Table D-16. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural yearling Chinook at index seining sites by week.

Week	Location	n	Mean	Min.	Max.	Total Captured
2/16/2003	Best Western	1	83	83	83	1
3/2/2003	Trimaran	1	97	97	97	1
3/23/2003	Trimaran	9	141	117	197	9
3/30/2003	Kellogg	1	146	146	146	1

Table D-17. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery yearling Chinook at index seining sites by week.

Week	Location	n	Mean	Min.	Max.	Total Captured
2/16/2003	Trimaran	5	192	180	199	5
3/23/2003	Trimaran	5	198	191	215	5
4/6/2003	Best Western	3	142	138	151	3
5/4/2003	Seacrest	2	120	108	132	2
	Alki	1	115	115	115	1

Table D-18. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural subyearling Chinook at the Soos Creek screw trap by week.

Week	n	Mean	Min.	Max.	Total Captured
1/26/2003	-	-	-	-	8
2/2/2003	89	38	32	44	130
2/9/2003	88	39	34	44	1954
2/16/2003	100	40	35	43	15211
2/23/2003	100	40	37	44	7567
3/2/2003	100	40	37	44	12293
3/9/2003	100	40	34	44	6287
3/16/2003	100	40	36	50	1243
3/23/2003	75	41	37	49	206

Table D-19. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural subyearling Chinook at the Kent screw trap on the Green River by week.

Week	Mean	Min.	Max.	n	Total Captured
5/11/2003	71	48	90	63	100
5/18/2003	74	59	88	62	62
5/25/2003	76	53	102	53	53
6/1/2003	82	69	111	53	53
6/8/2003	83	69	102	86	86
6/15/2003	87	72	109	17	17
6/22/2003	89	78	99	11	11

Table D-20. 2003 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery subyearling Chinook at the Kent screw trap on the Green River by week.

Week	Mean	Min.	Max.	n	Total Captured
5/11/2003	80	80	80	1	1
5/18/2003	79	56	108	99	391
5/25/2003	80	57	100	176	439
6/1/2003	83	62	114	153	166
6/8/2003	84	68	107	86	86
6/15/2003	89	75	115	38	38
6/22/2003	89	80	97	15	15

Table D-21. 2003 WRIA 9 Juvenile Salmonid Survival Study natural and hatchery subyearling Chinook mean fork lengths (mm) at index and screw trap sampling sites by week.

Week	Origin	WDFW Screw Trap (RM 34.5)	Soos Creek Screw Trap	Kent Screw Trap (RM 18)	Best Western Index (RM 13)	Trimaran Index (RM 7)	Kellogg Index (RM 1)	Seacrest Index (Elliott Bay)	Alki Index (Elliott Bay)
19-Jan-03	Natural				45				
26-Jan-03	Natural					38		40	
02-Feb-03	Natural	41	38				40		
09-Feb-03	Natural	41	39		41		39	40	41
16-Feb-03	Natural	40	40		42	42	42	43	
23-Feb-03	Natural	42	40		42	42	41		
02-Mar-03	Natural		40		41	43	44		
09-Mar-03	Natural	42	40				46		
16-Mar-03	Natural	42	40		41		46		
23-Mar-03	Natural	44	41			47	54		
30-Mar-03	Natural	44			47	47	49		
06-Apr-03	Natural	45			49	60	55		
13-Apr-03	Natural	50				57	66		
20-Apr-03	Natural	57			57	58	65		
27-Apr-03	Natural	61			56	66	76		
04-May-03	Natural	60			55	69			86
11-May-03	Natural	67		71	68	73	69	78	86
	Hatchery			80	71				
18-May-03	Natural	74		74	77	79	74	84	85
	Hatchery			79	81	77		87	
25-May-03	Natural	70		76	72	79	82	74	73
	Hatchery			80	80	82	85	73	81
01-Jun-03	Natural	75		82	89	78	74	78	74
	Hatchery			83	88	82	77	81	76
08-Jun-03	Natural	82		83	82	80	75	78	81
	Hatchery			84	86	82	76	79	84
15-Jun-03	Natural	82		87	85	84	74	82	85
	Hatchery			89	85	87	80	83	87
22-Jun-03	Natural	78		89		82	79	90	85
	Hatchery			89		85	82	100	89
29-Jun-03	Natural	86							
06-Jul-03	Natural	79						102	
	Hatchery						94	102	95
20-Jul-03	Natural							98	100
	Hatchery							104	103
03-Aug-03	Natural							107	

Table D-22. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural subyearling Chinook at Best Western seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
27-Jan-2002	38	-	38	38	1	1
10-Feb-2002	41	-	41	41	1	1
31-Mar-2002	42	2.9	38	45	4	4
7-Apr-2002	47	0.7	46	47	2	2
21-Apr-2002	46	-	46	46	1	1
5-May-2002	47	10.0	37	57	3	3
12-May-2002	49	5.3	41	62	25	25
19-May-2002	53	17.0	41	65	2	2
2-Jun-2002	69	14.6	48	110	42	42
9-Jun-2002	67	10.3	47	112	93	97
16-Jun-2002	73	8.6	53	83	16	16
23-Jun-2002	78	7.7	63	95	48	86
7-Jul-2002	76	-	76	76	1	1

Table D-23. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery subyearling Chinook at Best Western seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
2-Jun-2002	85	6.1	68	103	151	151
9-Jun-2002	82	6.1	64	99	126	137
16-Jun-2002	84	6.7	74	91	6	6
23-Jun-2002	86	7.6	65	103	34	34
7-Jul-2002	103	-	103	103	1	1

Table D-24. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery yearling Chinook at Best Western seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
19-May-02	158	-	158	158	1	1

Table D-25. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural subyearling Chinook at Trimaran seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
27-Jan-2002	38	3.7	33	43	6	6
10-Mar-2002	40	6.7	32	44	3	3
31-Mar-2002	46	4.4	37	49	6	6
7-Apr-2002	52	2.5	49	56	10	10
21-Apr-2002	55	3.8	52	59	3	3
5-May-2002	61	8.0	45	76	28	28
12-May-2002	66	9.2	59	72	2	2
19-May-2002	69	7.4	56	87	19	19
2-Jun-2002	76	7.0	68	85	4	17
9-Jun-2002	73	6.3	60	90	41	78
16-Jun-2002	74	6.6	59	93	93	122
23-Jun-2002	82	5.9	67	95	58	58
7-Jul-2002	81	4.5	75	93	28	28
14-Jul-2002	87	-	87	87	1	1

Table D-26. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery subyearling Chinook at Trimaran seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
5-May-2002	71	8.8	54	92	18	18
12-May-2002	70	-	70	70	1	1
19-May-2002	75	3.9	66	82	26	26
2-Jun-2002	79	5.2	58	88	40	157
9-Jun-2002	81	5.3	65	93	204	449
16-Jun-2002	83	5.8	65	96	197	282
23-Jun-2002	87	4.3	77	97	142	142
7-Jul-2002	88	4.1	78	97	24	24
14-Jul-2002	81	-	81	81	1	1

Table D-27. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural yearling Chinook at Trimaran seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
27-Jan-02	196	5.0	191	201	3	3

Table D-28. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery yearling Chinook at Trimaran seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
27-Jan-2002	176	7.4	168	182	3	3
24-Feb-2002	179	4.9	175	182	2	2
14-Apr-2002	146	16.3	134	157	2	2
21-Apr-2002	171	12.9	154	186	8	8
28-Apr-2002	169	13.4	159	178	2	2

Table D-29. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural subyearling Chinook at Kellogg Island seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
3-Feb-2002	38	-	38	38	1	1
24-Feb-2002	50	1.4	49	51	2	2
21-Apr-2002	64	-	64	64	1	1
9-Jun-2002	76	6.6	66	88	26	47
16-Jun-2002	82	1.0	81	83	3	3
23-Jun-2002	79	4.8	75	88	8	8
7-Jul-2002	81	7.9	67	96	24	24
14-Jul-2002	88	3.7	84	93	5	5
28-Jul-2002	109	-	109	109	1	1
25-Aug-2002	107	1.4	106	108	2	2

Table D-30. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery subyearling Chinook at Kellogg Island seining site.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
7-Apr-2002	49	-	49	49	1	1
21-Apr-2002	57	-	57	57	1	1
12-May-2002	78	-	78	78	1	1
19-May-2002	79	0.7	78	79	2	2
9-Jun-2002	81	6.1	57	100	150	320
16-Jun-2002	80	4.2	75	88	11	11
23-Jun-2002	81	6.8	70	87	7	7
7-Jul-2002	86	6.3	74	96	12	12
14-Jul-2002	94	-	94	94	1	1
28-Jul-2002	98	3.5	95	100	2	2

Table D-31. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural yearling Chinook at Kellogg Island seining site.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
10-Mar-02	248	-	248	248	1	1
28-Apr-2002	111	-	111	111	1	1

Table D-32. 2002 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery yearling Chinook at Kellogg Island seining site by week.

Week	Mean	S.D.	Min.	Max.	n	Total Captured
10-Mar-2002	310	-	310	310	1*	1
7-Apr-2002	325	49.5	290	360	2*	2
28-Apr-2002	144	-	144	144	1	1
5-May-2002	175	15.4	154	194	5	5
12-May-2002	174	-	174	174	1	1
19-May-2002	174	-	174	174	1	1

* These fish may have been more than one year old.

Table D-33. 2001 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural subyearling Chinook at Best Western seining site by week.

Sampling Date	Mean	s.d.	Min.	Max.	n	Total Captured
5/8/2001	58	6	42	81	111	111
5/15/2001	60	8	39	99	149	149
5/22/2001	62	10	44	97	181	181
5/29/2001	64	8	46	94	138	138
6/4-6/5/01	74	9	48	94	434	571
6/12/2001	76	10	50	109	162	162
6/19/2001	-	-	-	-	-	0
6/26/2001	82	6	69	91	14	14
7/3/2001	79	5	74	84	3	3
7/10/2001	85	6	72	93	15	15
7/23/2001	94	9	78	105	9	9
8/7/2001	-	-	-	-	-	0
8/23/2001	-	-	-	-	-	0
Total:	68	11	39	109	1,216	1353

Table D-34. 2001 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery subyearling Chinook at Best Western seining site by week.

Sampling Date	Mean	s.d.	Min	Max	n	Total Captured
5/8/2001	-	-	-	-	-	0
5/15/2001	75	N/A	75	75	1	1
5/22/2001	79	9	51	96	86	86
5/29/2001	76	10	54	98	32	32
6/4-6/5/01	83	10	55	164	512	674
6/12/2001	81	6	59	95	143	143
6/19/2001	-	-	-	-	-	0
6/26/2001	85	3	82	88	5	5
7/3/2001	-	-	-	-	-	0
7/10/2001	-	-	-	-	-	0
7/23/2001	-	-	-	-	-	0
8/7/2001	85	-	85	85	1	1
8/23/2001	97	-	97	97	1	1
Season Total	82	9	51	164	781.00	943

Table D-35. 2001 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of natural yearling Chinook at Best Western seining site by week.

Sampling Date	Mean	s.d.	Min.	Max.	n	Total Captured
5/8/01	-	-	-	-	-	0
5/15/01	113	8	102	133	13	13
5/22/01	126	26	100	154	5	5
5/29/01	139	N/A	139	139	1	1
Total:	118	16	100	154	19	19

Table D-36. 2001 WRIA 9 Juvenile Salmonid Survival Study mean fork lengths (mm), standard deviations, ranges, sample size (n) and total catch of hatchery yearling Chinook at Best Western seining site by week.

Sampling Date	Mean	s.d.	Min.	Max.	n	Total Captured
5/8/01	146	23	130	190	6	6
5/15/01	138	9	118	154	36	36
5/22/01	136	10	115	148	11	11
5/29/01	-	-	-	-	-	0
Total:	118	16	100	154	53	53

Table D-37. 2003 WRIA 9 Juvenile Salmonid Survival Study Chinook mean weights and range in grams taken from natural subyearling chinook collected at sampling sites by date.

Week	Location	n	Mean	Min.	Max.
24-Feb-07	Soos Creek	100	0.5	0.3	0.7
	RM 34.5	100	41.1	37	51
03-Mar-07	Soos Creek	100	0.5	0.3	0.7
	RM 34.5	100	40.9	38	49
10-Mar-07	Soos Creek	100	0.5	0.3	0.7
17-Mar-07	Soos Creek	100	0.5	0.4	1.2
24-Mar-07	Soos Creek	75	0.6	0.3	1.1
05-May-07	Alki	2	7.1	6.6	7.5
	Best Western	4	1.8	0.8	3
	Trimaran	5	3.0	2.3	3.6
12-May-07	Kellogg	2	4.4	3.9	4.8
19-May-07	Best Western	2	2.8	2.6	3
	Trimaran	4	5.5	4.3	6.7
26-May-07	Best Western	1	3.9	3.9	3.9
	Kellogg	3	5.6	4.5	7
16-Jun-07	Best Western	1	5.9	5.9	5.9
	Trimaran	5	7.6	5.7	9.6
23-Jun-07	Alki	4	6.0	5.2	7.6
	Marriott	4	7.3	4.3	9.4
	Seacrest	2	7.4	6.4	8.3
	Trimaran	5	6.2	4.4	8.1
07-Jul-07	Kellogg	2	11.8	9.9	13.6
21-Jul-07	Alki	1	9.4	9.4	9.4
	Seacrest	2	9.4	9	9.8

Table D-38. 2003 WRIA 9 Juvenile Salmonid Survival Study Chinook mean weights (grams), range and sample size (n) of hatchery subyearling Chinook collected at sampling sites by week.

Week	Location	n	Mean	Min.	Max.
5/19/2007	Trimaran	3	4.3	3.2	5.7
5/26/2007	Best Western	4	5.7	4.3	7.4
	Kellogg	5	4.5	3.7	5.1
6/16/2007	Best Western	5	7.1	5.5	8.3
	Trimaran	5	7.3	6	8.2
6/23/2007	Marriott	5	7.9	5.9	9.1
	Trimaran	5	7.6	5.3	10.2
	Seacrest	1	10.9	10.9	10.9
	Alki	5	9	5	12.4
7/21/2007	Seacrest	3	11.7	8.9	13.6
	Alki	2	10.7	9	12.3

Table D-39. 2003 WDFW Green River screw trap mean fork lengths (mm), standard deviations, ranges, sample size (n) and catch of natural subyearling Chinook by week (WDFW 2003).

Week	Mean	s.d.	Min	Max	n	Total Subyearling Catch
03-Feb-03	41	1.28	37	45	102	1256
10-Feb-03	41	1.45	38	48	231	854
17-Feb-03	40	2.18	37	54	150	2671
24-Feb-03	42	1.92	38	51	207	2099
03-Mar-03	42	2.80	38	65	194	4877
10-Mar-03	42	1.62	38	48	155	2375
17-Mar-03	42	3.94	38	66	124	1109
24-Mar-03	44	5.20	38	69	83	464
31-Mar-03	44	4.31	40	54	19	102
07-Apr-03	45	6.05	38	68	57	136
14-Apr-03	50	9.23	38	68	36	127
21-Apr-03	57	7.06	42	69	26	85
28-Apr-03	61	5.76	54	75	11	78
05-May-03	60	6.69	42	76	33	80
12-May-03	67	9.36	49	81	13	90
19-May-03	74	8.29	57	91	22	65
26-May-03	70	10.31	42	87	62	255
02-Jun-03	75	9.43	48	95	48	262
09-Jun-03	82	4.64	73	92	18	491
16-Jun-03	82	6.77	67	94	30	257
23-Jun-03	78	8.08	67	90	7	37
30-Jun-03	86	12.12	62	98	7	17
07-Jul-03	79	13.99	59	97	5	5

Table D-40. 2002 WDFW Green River screw trap mean fork lengths (mm), standard deviations, ranges, sample size (n) and catch of natural subyearling Chinook by week (WDFW 2003).

Week	Mean	s.d.	Min	Max	n	Total Subyearling Catch
2/4/02	39	0.8	38	40	5	107
2/11/02	40	2.1	36	44	56	246
2/18/02	40	2.0	36	44	29	1209
2/25/02	40	2.1	35	51	156	467
3/4/02	40	2.0	35	46	97	758
3/11/02	40	1.7	37	45	117	2977
3/18/02	42	3.0	37	61	318	1006
3/25/02	42	2.2	38	52	146	1143
4/1/02	41	2.1	37	53	178	1391
4/8/02	42	1.9	39	50	87	797
4/15/02	44	3.2	39	54	55	678
4/22/02	46	4.2	39	59	105	820
4/29/02	50	7.6	39	72	56	207
5/6/02	59	7.9	49	73	14	155
5/13/02	61	9.3	45	78	13	150
5/20/02	59	10.2	38	73	37	147
5/27/02	64	10.3	51	95	29	147
6/3/02	67	9.3	49	87	42	527
6/10/02	76	9.7	60	90	14	882
6/17/02	77	9.7	59	98	36	1383
6/24/02	74	10.6	52	90	39	898
7/1/02	80	9.5	64	98	26	981
7/8/02	86	9.8	59	105	32	510

Table 41. 2001 WDFW Green River screw trap mean fork lengths (mm), standard deviations, ranges, sample size (n) and catch of natural subyearling Chinook by week (WDFW 2002).

Week	Mean	s.d.	Min	Max	n	Total Subyearling Catch
1/31/01	40	1.6	36	41	8	143
2/5/01	39	1.8	35	43	48	443
2/12/01	41	1.7	34	45	145	534
2/19/01	41	1.7	38	45	20	488
2/26/01	41	1.7	34	45	246	5593
3/5/01	41	1.9	37	58	652	9897
3/12/01	41	1.7	36	55	742	8055
3/19/01	42	2.4	36	62	714	6280
3/26/01	41	2.1	36	54	364	2885
4/2/01	42	3.3	37	62	204	1409
4/9/01	43	6.0	38	66	131	268
4/16/01	46	7.6	38	68	64	130
4/23/01	49	8.6	38	73	24	230
4/30/01	60	9.0	47	80	27	348
5/7/01	68	8.1	48	82	22	318
5/14/01	63	10.0	40	83	32	2519
5/21/01	70	9.3	49	96	79	2688
5/28/01	75	8.3	48	87	37	3480
6/4/01						2028
6/11/01	87	11.8	63	115	26	6962
6/18/01	88	9.6	62	123	86	813
6/25/01	90	6.7	78	108	48	613
7/2/01						185
7/9/01	89	6.5	74	100	31	130
7/16/01						86
7/23/01						25
7/30/01						6